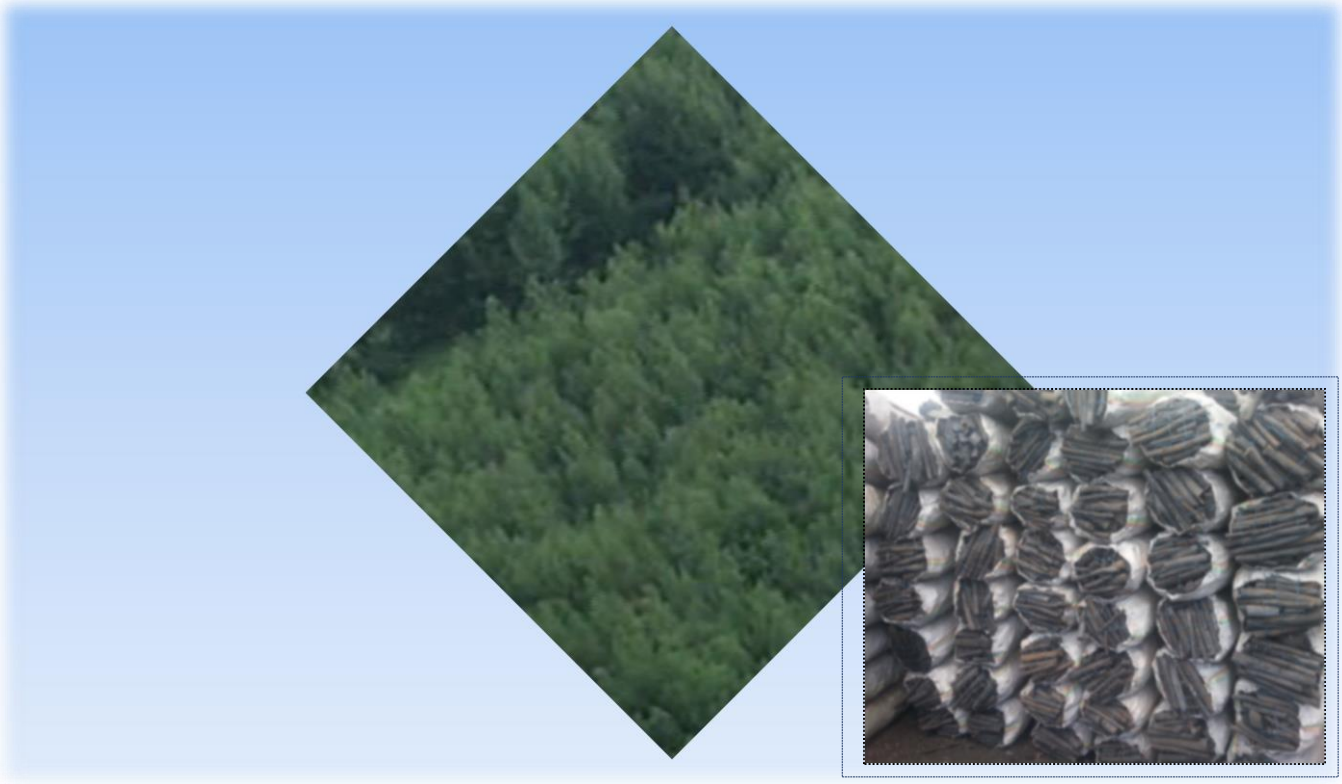


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GIS AND REMOTE SENSING BASED LAND USE/LAND COVER CHANGE DETECTION AND PREDICTION IN FAGITA LEKOMA WOREDA, AWI ZONE, NORTH WESTERN ETHIOPIA



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GIS and Remote Sensing Based Land Use/Land Cover Change Detection and Prediction in FagitaLekomaWoreda, Awi Zone, North Western Ethiopia

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Table of Contents

Acknowledgment----------i
Table of Contents----------ii
List of Figures----------v
List of Tables----------vi
Acronyms----------vii
Abstract----------viii
CHAPTER ONE
1. INTRODUCTION
1.1 Background----------1
1.2 Statement of the Problem----------3
1.3 Objectives of the Study----------4
1.4 Research Questions----------4
1.5 Expected Outputs of the Research----------5
1.6 Scope of the Study----------5
CHAPTER TWO
2. LITERATURE REVIEW
2.1 Land Use and Land Cover----------6
2.2 Land Use/Land Cover Change----------6
2.3 Studies Done on Land Use/Land Cover in Ethiopia----------7
2.4 Causes of Land Use/Land Cover Change----------9
2.4.1 Population Growth----------10
2.4.2 Institutional Factors----------11
2.5 Effects of Land Use/Land Cover Change----------11
2.5.1 Effects on Forest and Biodiversity ----------11
2.5.2 Effects on Soil----------12

2.6 Causes of LULC Change and Its Impact in Ethiopia----------12
2.7 Remote Sensing----------14
2.8 Image Classification----------15
2.8.1. Object-Oriented Image Classification Methods----------16
2.8.2. Pixel-Based Image Classification Methods----------16
2.8.3. Contextual Image Classification Approaches----------17
2.8.4 Post Classification Approaches----------17
2.9 Change Detection Analysis----------17
2.10 Geographic Information System----------18
2.11 Marcov Chain Model----------19
CHAPTER THREE
3. DATA AND METHDOLOGY
3.1 Description of the Study Area----------21
3.1.1 Location of the Study Area----------21
3.1.2 Physiographic Nature of the Study Area----------22
3.1.3 Population----------25
3.2 Data Acquisition and Source----------26
3.3 Development of a Classification Scheme----------30
3.4 Accuracy Assessment ----------30
3.5 Methods of Data Analysis----------31
3.6 Software Used----------32
CHAPTER FOUR
4. RESULTS AND DISCUSSIONS
4.1 Land Use/Land Cover Dynamic----------33
4.2 Accuracy Assessment of the Classification----------38

4.2.1 User's Accuracy----------38

4.2.2 Producer's Accuracy----------38

4.2.3. Overall Accuracy----------40

4.3 Land Use/Land Cover Change: Trend, Rate and Magnitude----------41

4.3.1 Cultivated Land----------41

4.3.2 Grassland----------43

4.3.3 Wetland----------45

4.3.4 Forests----------46

4.3.5 Urban Area----------51

4.4 Transition Probability Matrix----------54

4.5 Land Use/Land Cover Change Projection----------55

4.6 Socioeconomic Consequences of LULC Change----------57

CHAPTER FIVE

5. CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion----------60

5.2 Recommendations----------61

References

Appendix

List of Figures

Fig. 3.1 Map of the Study Area----------21

Fig.3.2 DEM Map of FagitaLekomaWoreda----------22

Fig. 3.3 Slope Map of FagitaLekomaWoreda----------23

Fig. 3.4 Temperature Data of the Study Area----------24

Fig. 3.5 Rainfall of the Study Area----------24

Fig. 3.6 Total Population of the Study Area----------26

Fig. 3.7 False Color Composite of 1973(left), 1987(middle) and 2015(right) ----------27

Fig. 3.8 General Procedure of the Study----------29

Fig. 4.1 LULC Map of FagitaLekomaWoreda in 1973----------33

Fig. 4.2 LULC Map of FagitaLekomaWoreda in 1987----------35

Fig. 4.3 LULC Map of FagitaLekomaWoreda in 2015----------36

Fig. 4.4 Pie Chart Representation of LULC Classes for the Study Years----------37

Fig. 4.5 LULC Change Map between 1973 and 1987----------44

Fig. 4.6 Forest Coverage of the study Area in 1973----------46

Fig. 4.7 Forest Coverage of the study Area in 1987----------47

Fig. 4.8 Forest Coverage of the study Area in 2015----------47

Fig. 4.9 Photo of *Acacia decurrens* Forest in the Study Area ----------50

Fig. 4.10 Photos of *Acacia dicurrens* ready for Charcoal Production (left) and in Process of Production (right) ----------51

Fig. 4.11 LULC Change Map between 1987 and 2015 ----------52

Fig. 4.12 LULC Change Comparison between 1973 and 2015----------53

Fig. 4.13 LULC Projection for 2043----------56

Fig. 4.14 Charcoal Produced from *Acacia decurrens* in the Study Area----------57

List of Tables

Table 3.1 Total Population of FagitaLekoma Woreda1984-2014----------25

Table 3.2 Data Source Characteristics----------27

Table 4.1 LULC Class Distributions of Fagita of 1973----------34

Table 4.2 Confusion Matrix for the LULC Map of 1973----------39

Table 4.3 Confusion Matrix for the LULC Map of 1987----------39

Table 4.4 Confusion Matrix for the LULC Map of 2015----------40

Table 4.5 Post-classification Matrix of Study Area between 1973 and 1987----------42

Table 4.6 Post-classification Matrix of Study Area between 1987 and 2015----------49

Table 4.7 Post-classification Matrix of Study Area between 1973 and 2015----------53

Table 4.8 Summary of Magnitude and Rates of Change in LULC of the Study Area between 1973-1987 and 1987-2015----------54

Table 4.9 Transitional Probability Matrix Table ----------55

Table 4.10 Projected LULC for 2043----------56

Acronyms

ANRS	Amhara National Regional State
CSA	Central Statistical Authority
DEM	Digital Elevation Model
EMA	Ethiopian Mapping Agency
ERDAS	Earth Resource Data analysis System
ETM	Enhanced Thematic Mapper
FLWFEDO	FagitaLekomaWoreda Finance and Economic Development Office
FLWARDO	FagitaLekomaWoreda Agriculture and Rural Development Office
FLWRO	FagitaLekomaWoreda Revenue Office
GIS	Geographic Information System
GPS	Geographical Positioning System
ha	hectare
IGBP	International Geosphere and Biosphere Program
IHDP	International Human Dimensions Program on Global Environmental Change
K_{hat}	Kappa coefficient
LUCC	Land Use Land Cover Change
LULC	Land Use Land Cover
NMA	National Meteorological Agency
MS	Micro Soft
MSS	Multispectral Scanner
NIR	Near Infra-Red
OIES	Global Change Institute of the Office of Interdisciplinary Earth Studies
RGB	Red Green Blue
RS	Remote Sensing
SSE	Supervised Spatial Encoder
TM	Thematic Mapper
USGS	United States Geological Survey
UTM	Universal Transvers Mercator

Abstract

This project examines the use of GIS and Remote Sensing in mapping Land Use/Land Cover in FagitaLekomaWoreda between 1973 and 2015 so as to detect and analyze the changes that has taken place in their status between these periods.

In order to achieve these, satellite data of Landsat MSS for 1973, TM for 1987 and ETM for 2015 have been obtained and preprocessed using ERDAS Imagine. The Maximum Likelihood Algorithm of Supervised Classification has been used to generate land use and land cover maps. For the accuracy of classified Land Use/Land Cover maps, a confusion matrix was used to derive overall accuracy and results were above the minimum and acceptable threshold level. Post-classification comparison change detection method was employed to identify gains and losses between Land Use/Land Cover classes. Subsequently, an attempt was made to predict for the next 28 years change based on the observed Land Use/Land Cover changes using Marcov Chain Model.

The satellite image results show that cultivated land increased in the first period but decline in the second and the entire study periods.Grassland increased in the first period and decreased in the second period. Wetland is the most converted cover type during the entire study period.In the 42 years, forest lands expanded by over 255% of the original forest cover what was existed at the base year. The impact of this LULC change is more significant on the socioeconomic condition and status of the study area. Urban area which was not found in the first two study years satellite image result have 2.1% proportion in 2015 Land Use/Land Cover classification.

Keywords: FagitaLekoma; Image Classification; GIS; Land Use/Land Cover Change; Marcov Chain Model; Remote Sensing

CHAPTER ONE

1. INTRODUCTION

1.1 Background

Land use/land cover change has become a central and important component in current strategies for managing natural resources and monitoring environmental changes(Rawat, 2013).Land use is the intended employment of land management strategy placed on the land cover by human agents or land managers to exploit the land cover and reflects human activities such as industrial zones, residential zones, agricultural fields, grazing, logging and mining among many others(Zubair, 2006). On the other hand, land cover is defined by the attributes of the earth's land surface captured in the distribution of vegetation, water, desert and ice and the immediate subsurface, including biota, soil, topography, surface and groundwater and it also includes those structures created solely by human activities such as mine exposures and settlement(Lambin*et al.*, 2003; Baulies and Szejwach, 1997).

Land use and land cover are dynamic. Changes may involve the nature or intensity of change but may also include spatial (forest abatement at village level, or for a large-scale agro industrial plant), and time aspects(Prakasam, 2010).

The conversion of natural land to cropland, pasture, urban area, reservoirs, and other anthropogenic landscapes represents the form of human impact on the environment(Granahan*etal*., 2005). Roughly 40% of earth's land surface is under agriculture, and 85% has some level of anthropogenic influence(Sanderson *et al*., 2002). Therefore, large-scale land cover change is largely a rural phenomenon, but many of its drivers can be traced to the consumption demands of the swelling urban population(Carr, 2004).

The land use/land cover pattern of a region is an outcome of natural and socio–economic factors and their utilization by man in time and space. Land is becoming a scarce resource due to immense agricultural and demographic pressure(Zubair, 2006). Hence, information on land use/land cover and possibilities for their optimal use is essential for the selection, planning and implementation of land use system to meet the increasing demands for basic human needs and

welfare. This information also assists in monitoring the dynamics of land use resulting out of changing demands of increasing population.

In Ethiopia, too, fast population growth and uneven spatial distribution of population have been affecting resource use, leading to its gradual deterioration. Rapid population growth is resulting in increased demands for additional arable land which is surely not adequately available. Population growth leads further to unnecessary natural resource exploitation such as forest clearing both for farming and settlement purposes, short fallow periods, and land fragmentation which has a direct adverse effect on agricultural output(Mamo, 1990; Teferra, 2009).

Land degradation results mainly due to population pressure which leads to intense land use without proper management practices. Over population makes people move towards sensitive areas like highlands. In such areas land use without considering the slope and erodibility leads to severe erosion and related problems. The influence of road construction and other comparable disturbances of landscape on erosion and on landslides, and other mass movements on hilly area are well known(Prakasam, 2010).

Most of the population of Ethiopia is settled on the highlands, with the northern and central highlands being the oldest settled regions of the country. These regions are the most exploited and environmentally degraded areas in the entire country. Due to the shortage of arable land, land is continuously utilized year after year, thus giving diminishing yields(Kebede and Jacob,1988; Assefa and Zegeye, 2003).

FagitaLekomaWoreda which is located in the North Western part of the country is one of the exploited and degraded areas of the region. In the past ten and fifteen years the woreda had been with in a serious problem mostly the south western part. There are observable signs which indicate the existence of land degradationdue to over plowing and clearing of forests for different purposes. The rural poor people have been also degrading the natural forest resources to sustain their livelihoods. Because of small landholding size and shortage of land in the woreda, plowing steep slopes with marginal output is common practice which has led to land and other natural resources degradation. The ability of the land to give production was becoming low and the peoples had started to abandon their land because it becomes incapable of even to grazing. Through the initiation from government,the community started to cover their land byvegetation. The peoples from Addis Kidamtown(the capital town of FagitaLekomaWoreda) area

easilystarted to grow Eucalyptus and *Acacia decurrens* trees by hiring land from farmers. Through time the second one i.e. *Acacia decurrens* was became more preferable because it is functional relatively in a short period of time and rehabilitating ability of soil. Then through process by observing its advantage at both economical and rehabilitation aspect the farmers adopted the system. As a result the spatial and temporal land use/land cover(LULC) in general and the forest coverage of the woredain particular is changing.

Such local-level dynamics is very important in determining the status of land and ecosystem health. Hence, information on land use, land cover, and possibilities for their optimal use is essential for the selection, planning, and implementation of land use schemes to meet the increasing demands for basic human needs and welfare. This information also assists in monitoring the dynamics of land use resulting out of changing demands of increasing population. Studies of rates, extents, patterns, causes, and implications of LULC dynamics at local level can help to design appropriate land management practices, strategies and policies.

Gathering information about Land Use/Land Cover changes is fundamental for a better understanding of the relationships and interactions between humans and the natural environment. RS data have been one of the most important data sources for studies of LULC spatial and temporal changes. In fact, multi-temporal RS datasets, opportunely processed and elaborated, allow to map and identify landscape changes, giving an effective effort to sustainable landscape planning and management(Dewan*et al*., 2009). In particular, by means of the integration RS and GIS techniques, it is possible to analyze and to classify the changing pattern of LULC during a long time period and, as a result, to understand the changes within the area of interest.The availability of time-series dataset is essential to understand and monitor the change process, in order to characterize and locate the evolution trends at a detailed level.

1.2 Statement of the Problem

Land as a finite and a potentially productive natural resource represent our basic food production facility. However, the diversity of residents and intensive use of the resources through the increasing of population coupled with economic activities and global market drive unprecedented land use and land cover changes(Ezeaku and Davidson, 1992). These changes lead to transformations in the hydrological, ecological, geomorphologic and socioeconomic

systems and which are often neglected by both rural and urban administrations. Thus, special attention and continuous assessment are required for monitoring and planning for a given area development and decision making.

LULC change can impact the socio-economic status of the rural population(Lambin and Giest, 2003). Agricultural productivity, which may determine rural income levels, wealth and education, can be affected by the consequences of LULC changes. Therefore, understanding of the complex interaction of these changes in their temporal and spatial patterns and processes is the baseline to formulate focused and targeted policy interventions in rural development and environmental management.

FagitaLekomaWoreda has witnessed remarkable LULC change, mainly as a result of deteriorating on agricultural productivity of land.This deterioration of the land is because of the nature of the topography, population size increment, over cultivation and over grazingwhich enforcethe inhabitants to change their land use practice. This has therefore resulted in an increased LULC change and its modification and alterations in status over time without any detailed and comprehensive attempt(as it isprovided by Remote Sensing and GIS techniques) to evaluate this status as it changes overtime with a view to detecting the LULC change.

1.3 Objectives of the Study

The main objective of this study is **to detect and analyze LULC changes in FagitaLekomaWoreda by integrating RS and GIS techniques**. The specific objectives of this study were:

- to produce LULC maps of the study area for years 1973, 1987 and 2015;
- to analyze the dynamics of LULC changes as well as its spatial distribution and patterns within 1973,1987 and 2015;
- to quantify gain and losses of land cover classes, examine land use transitions and asses spatial trends of changes;
- to forecast the future pattern of LULC in the study area(from 2015 to 2043).

1.4 Research Questions

The following research questions were designed to guide the study:

- What were the major LULC changes exhibited on the selected study period?
- How was the spatial pattern of LULC class changes during the study period?
- What sort of LULC patterns would likely be exhibited in the future in the study area, given the present scenario?

1.5Expected Outputs of the Study

- Quantifiedvalues for the extent of LULC changes for the study area.
- Maps which show as afforestation is currently growing in the area and can indicate land management information and rehabilitation of resources.
- Predicted valuesthat indicate what will happen in the future if current land use systems continue for the study area.
- The research will add considerable contribution to the benefit of the region in the natural resource development and more rehabilitation.
- The final output data will be available as digital map and associated spatial database that will be part of the future national and/or regional LULC database and can be used for governmental and/or non-governmental organizations engaged in practical implementation and/or further scientific research work.

1.6Scope of the Study

The use of GIS and Remote Sensing technologies to LULC change detection and analysis is a rapidly expanding field. This project will only give how GIS and Remote Sensing can be used as potential analytical tools to detect and analyze LULC change in FagitaLekomaWoreda. It doesn't cover some adjacent areas of the woreda.

CHAPTER TWO

2. LITERATURE REVIEW

2.1 Land Use and Land Cover

The land use/ land cover change science plan and implementation strategy sought multiple ways to deal with this reality, the first being to distinguish land "use" from land "cover" (Turner *et al*. 1995; Lambin and Geist,2006).

Land cover has been defined by the attributes of the Earth's land surface and immediate subsurface, including biota, soil, topography, surface and groundwater, and human (mainly built-up) structures(Turner *et al*. 1995; Lambin*et al*. 2003).

Land use has been defined as the purposes for which humans exploit the land cover. It involves both the manner in which biophysical attributes of the land are manipulated and the intent underlying that manipulation, i.e., the purpose for which the land is used. Exemplary classes denoting intent or purpose are forestry, parks, livestock herding, suburbia and farmlands(Turner *et al*. 1995). Land management, biophysical manipulation or the techno-managerial aspect of a land-use system, by contrast, refer to the specific ways in which humans treat vegetation, soil, and water for the purpose in question. Examples are the use of fertilizers and pesticides, irrigation for mechanized cultivation in drylands, or the use of an introduced grass species for pasture, and the sequence of moving livestock in a ranching system(Lambin and Geist,2006).

2.2 Land Use/Land Cover Change

Land use and land cover changes became prominent as a research topic on the global environmental change several decades ago with the idea of processes in the earth's surface influence climate. In early 1980's the significance impact of land use and land cover change on the global climate via carbon cycle was understood where terrestrial ecosystems acted as a source and sinks due to the changes. Following this, the forthcoming volume of the 1991 Global Change Institute of the Office of Interdisciplinary Earth Studies(OIES) dedicated to land use and land cover changes at global level by explaining the major recent trends of changes, their consequences in environment, human causes on it as well as data and modeling of changes(Meyer and Turner, 1992).

Latter, under the support of land use and land cover change project of the International Geosphere and Biosphere Programme (IGBP) and International Human Dimensions

Programmeon Global Environmental Change (IHDP), the research community has identified three basic issues. These understood the causes of land use and land cover changes, how to quantify it and how to apply models of predicting the changes(Lambin*et al*, 2003).

Conversion and modification are the two forms of land cover changes described by Meyer and Turner(1992) where the former is a change from one class of land cover to another (e.g from grassland to cultivated land). The latter is, however, a change within a land cover category (e.g thinning of a forest or a change in composition).

Whatever the type of changes in land cover, they encompass changes in biotic diversity, actual and potential primary productivity, soil quality, runoff and sedimentation rates, and other such attributes of the terrestrial surfaceof the Earth(Steffen *et al*., 2004; DeFries*et al*., 2004; Lambin and Geist,2006). Four aspects of change detection which are important when monitoring natural resources(Macleod and Congation, 1998 cited in Zabair, 2006):

i. Detecting the changes that have occurred
ii. Identifying the nature of the change
iii. Measuring the area extent of the change
iv. Assessing the spatial pattern of the change

The basis of using remote sensing data for change detection is that changes in land cover result in changes in radiance values which can be remotely sensed. Techniques to perform change detection with satellite imagery have become numerous as a result of increasing versatility in manipulating digital data and increasing computer power.

2.3 Studies Done on Land Use/Land Cover in Ethiopia

Researches on land use and land cover change in Ethiopia involved in different regions and disciplines depending on the availability of data and tools to perform analysis and their interest. Most of the studies have focused on deforestation, the expansion of cultivated land to land degradation, river catchments and watersheds, urban growth, natural ecosystems and forests as well as the associated consequences. In general almost all have reached to the conclusion thatcultivated land, rural and urban settlements as well as open lands expanded in large amount at the expense of natural vegetation including forest, wooded land and shrub land.

Berhanu*et al*.(1998) has reported that 3.1% of natural forest is lost annually due to shifting cultivation, commercial agriculture, fuel wood collection, urbanization, forest fire, poor utilization and logging.Berhane(2007) has also reported that 693.84ha of forest land is changed

in to other land use/land covers annually in Dendi District. Gete and Hurni(2001) reported an expansion of cultivated land at the expense of natural forest cover between 1957 and 1982 in Dembecha area, north-western Ethiopia. The study also investigated a series trend of land degradation resulted due to the expansion of cultivated land on steep slopes at the expense of natural forests. Aklilu*et al*.(2007) showed a significant decline in natural vegetation cover, however, there was an increase of plantation in Beressa watershed, in the central highlands of Ethiopia between 1957 and 2000. Eleni*et al*.(2013) also showed a significant decrease of natural woody vegetation of the Koga catchment since 1950 due to deforestation in spite of an increasing trend in eucalyptus tree plantations after the 1980's. Woldeamlk and Solomon(2013) reported a reduction of natural vegetation cover, but an expansion of open grassland, cultivated areas and settlements in Gish Abay watershed, north-western Ethiopia.

Tekle and Hedlund(2000) reported an increase of open areas and settlements as the expense of forests and shrub land between 1958 and 1986 in Kalu District, Southern Wello, Ethiopia. Within 28 years open area, urban and natural lands showed an expansion by 33.3%, 19.5% and 75% respectively at the expense of shrub land and forest. A similar study by Belay(2002) reported a significant conversion of natural vegetation cover to cultivated land between 1957 and 1986 in Derekolli catchment of the South Welo Zone of Amhara Region, Ethiopia. Mengistie*etal*.(2013) investigated a significantly reduction of natural forest cover and grasslands, but an increase of croplands between 1973 and 2012 in Munessa, Shashemene landscape of the Ethiopian Highlands.

The impacts of land use and land cover changes on the hydrological flow regime of the watershed have been reported in many studies. The impact is through altering the balance between rainfall and evaporation and the runoff response. Alemayehu(2011) reported an increment of a direct runoff Gum-Selassa and Maileba catchments annually from 1964 to 2006 in both catchments due to long-term changes of land use and land cover. It was also reported by Amare(2013) that land use and land cover changes affected the stream flow of GilgelAbbay Watershed, Ethiopia. His study identified that there was an increase of stream flow by 16.26m^3/s during wet months and decreased by 5.41m^3/s from 1986 to 2001 as a consequence of conversion of cultivated land.

Land use and land cover changes in response to urban growth also reported by some studies that,Mesfin(2009) identified a significantly increase of urban areas from 34% in 1986 to 51% in

2000 in Addis Ababa, Ethiopia by the expense of agricultural land and vegetated areas driven by population growth. Expansion of urban areas annually from 1957 to 2009 has been identified by Nigussie*et al*.(2012) in the urban fringe of Bahir Dar area as a consequence of increasing population.Dorosh and Schmidt(2010) also reported a significant urban growth for the last three decades as a result of increase in population of Ethiopian highlands.

Muluneh and Arnalds(2011) cited on Haile(2004) that unsustainable growth of population contributed to environmental degradation especially in most populated areas such as in Ethiopian highlands.

From most of these studies it is evident that population pressure is one of the major drivers of land use and lan`d cover changes through destruction of forest and vegetation cover for the purpose of agricultural and urban expansion as discussed by Gete and Hurni(2001) and Aklilu*et al.*(2007). Population growth coupled with migration from rural to cities leads to further expansion of urban areas at the expense of vegetation cover which is commonly practiced in western highlands of Ethiopia according to Gete and Hurni(2001) study.

2.4 Causes of Land Use/Land Cover Change

The question of what factors drive land-use and land-cover change remains largely unanswered(Turner and Meyer, 1994). Recently, human activities and social factors were recognized to have a paramount importance for understanding of land-use and land-cover change(Geist and Lambin, 2002).

Land use is never static; it constantly changes in response to the dynamic interaction between underlying drivers and proximate causes(Lambin and Geist, 2003). The conceptual understanding of proximate causes and underlying forces has a crucial importance to identifying the causes of land-use and land-cover changes(Turner and Meyer, 1994).

LULC changes can occur through the direct and indirect consequences of human activities to secure essential resources. This may first have occurred by means of burning of areas to develop the availability of wild game and it accelerated with the birth of agriculture, resulting in extensive clearing such as deforestation and earth's terrestrial surface management that takes place today(Ellis and Pontius, 2006 cited in Jamal, 2012). Verburg*et al*.(2002) showed that causes of land use and land cover change can be categorized as direct (proximate) or indirect (underlying). The direct causes comprise human activities that could arise from the continuous use of land and directly alter land cover which reflect that human are driving forces. They are

generally operated at local levels and explain how and why local land cover and ecosystem processes are modified directly by humans. These causes include agricultural expansion, wood extraction, infrastructure expansion and others that change the physical state of land cover(Turner and Meyer, 1994). On the other hand, indirect causes are fundamental forces that strengthen the more direct causes of land cover changes. These causes are resulted due to the complex interaction of social, political, economic, technological and biophysical variables(Verburg*et al*. 2002).

These two major categories of causes operate at different levels. Proximate causes operate at the local level (individual farms, householders, or communities); on the contrary, the sources of underlying causes are at regional and national levels such as districts, provinces, or countries. Underlying causes are often external and beyond the control of local communities(Lambin*et al*., 2003).

2.4.1 Population Growth

Historically, population was regarded as the most important and the only driving force behind global change. However, currently it is understood that environmental changes have many driving forces that are closely interrelated, population being only one of them(Reindfuss and Adamo, 2004).

Studies conducted at longer time scales show that land cover change had and still has tremendously been influenced by both the increase and decrease of a given population(Lambin*et al*., 2003). In contrast, within the time range of a few decades, population growth, poverty, and infrastructure are not good indicators of the status of land cover changes. Instead, responses from individual and communities to changing economic conditions and institutional factors often affect land use/cover change(Lambin and Geist, 2003).

In most developing countries population growth has been a dominant cause of land-use and land-cover change than other forces(Sege, 1994). There is a significant statistical correlation between population growth and land cover conversion (forest change) in most of African, Asian, and L/American countries(Turner and Meyer, 1994).

The debated issues regarding the impact of population on environment and economic development have been between two schools of thought: Neo- Malthusian and Boserupian. Neo-Malthusians believe population growth to have a negative impact on economic development and environmental enhancement. According to their view, population growth has a greater power

than that in the land itself, to influence food production, and this is because population increases geometrically whereas food production increases arithmetically(Stone, 1993).

On the contrary, Boserupians have an optimistic vision regarding the link between population growth and food production and even quality of the environment (Turner, 2001). Rapid population growth helps to develop good efficiency and technological innovation instead of hindering the living standard of the people. The case study in Machakos, Kenya, has been taken as an example and helped them develop a model that describes the positive impact of population growth(Tiffen*et al*., 1994).

2.4.2 Institutional Factors

The understanding of institutional causes (i.e. political, legal, economic, and traditional) and their interaction with individual decision making are important in explaining land use changes. Institutional causes need to be considered at micro and macro levels because the implementation of macro policies is practiced at the local level. Land-use and land-cover changes are influenced significantly when macro policies undermine local policies in that the structure of local and national polices may determine local people's access to land, capital, technology, and information(Lambin and Geist, 2003).

Lack of well-defined policies and weak institutional enforcement may facilitate changes of land use. On the other hand, restoration of land use is possible if there are appropriate land use policies in place. In most developing countries communal (traditional) land holding systems have been shifted to a formal (state) holding system(Lambin*et al*., 2003). The policy in developing countries of price control on agricultural in-put and out-put and self-sufficiency in food have all influenced land use changes(Turner *et al*., 1993).

2.5 Effects of Land Use/Land Cover Change

2.5.1 Effects on Forest and Biodiversity

One obvious consequence of land-use and land-cover change, particularly of deforestation is the shortage of fuel-wood. As population increases household energy consumption also increases. Of the total population of the world, 30 to 40 percent largely depends on fuel wood and charcoal. For the poor in rural areas, it is not only a source of energy but a means of income generation too. "In many parts of the developing world, fuel is scarcer and more expensive than the food that is eaten..."(Williams, 1995). Globally, about 29 percent of the land surface was originally

under forest cover. Presently, however, it is only a fifth of this original which remains undisturbed(FAO, 2001).

Land-use and land-cover change and changes in land cover due to land use are not necessarily land degradation(Turner and Meyer, 1994). The impact of the change on the land is measured in terms of the productivity of the converted land(Turner *et al*., 1995). A major impact of land-use and land-cover is on soil and biotic resources. For example, the annual loss of plant species in tropical Africa is as high as 27,000. The loss of biodiversity due to land-use and land-cover changes takes place at multiple levels (landscape, ecosystem and species), and in multiple dimensions (structure and function)(Turner *et al*., 1995).

2.5.2 Effects on Soil

LULC patterns are interrelated with the types and properties of soils. The rate and severity of soil erosion and land degradation partly depends on land use pattern. The problem of soil erosion starts with the removal of land cover (natural vegetation) for various purposes. The relationship between land use and soils is two dimensional(land use affects soils and in reverse soils affect land use).

2.6 Causes of LULC Change and Its Impact in Ethiopia

Many researchers recognized that the main cause of LULC change and related impacts in Ethiopia are anthropogenic in origin even though natural processes may also contribute to change. The pressure exerted by population growth is taken as the main factor. Given the low level of economic development, increase in population exerted pressure on change in the environment by conversion of woodlands and shrub lands into croplands that resulted in loss of natural vegetation cover(Dougall*et al*. 1975, Virgo & Munro, 1977).

Land cover changes due to human activities drive land use and hence a single class of cover could support multiple uses (forest used for combinations of timbering, slash and burn agriculture, fuel wood collection and soil protection). On the other hand, a single system of land use can maintain several covers (as certain farming systems combine cultivated land, improved pasture and settlements).In most developing countries population growth has been a dominant cause of land-use and land-cover change than other forces(Sege, 1994). There is a significant statistical correlation between population growth and land cover conversion (forest change) in most of African, Asian, and L/American countries(Turner and Meyer, 1994).

Similarly, in Ethiopia population pressure has been found to have negative effect on shrublands, riverine vegetation and forests in Kaludistrict(Kebrom, 2000), riverine trees in Chemoga watershed (Woldeamlak, 2002), and natural forest cover in DembechaWereda north-western Ethiopia (Gete and Hurni 2001). These works support Neo-Malthusian school of thought. Unlike these studies, Muluneh (2004) reported for Sebat Bet Guraghe that population growth was found to have a positive impact on forest cover which supports Boserupian school of thought.

According to Bezuayehu*et al*.(2002), the increase in the human population has reduced land holding per capita and created pressure on limited land and for agricultural production. In addition, those who cannot produce enough cut forests and trees for fuel, wood and charcoal to earn a living. For example 22% and 33% of households in Melkedera Peasant Association in Ambo Woreda depend occasionally and regularly, respectively on nearby forests for their livelihood. Also, the removal or destruction of vegetation cover through overgrazing and bush burning etc.

In the study areathe increase in population with little or no change in technology, the different land policies in the past and the poor land management practices have resulted in the change of the land cover and causing serious land degradation in the area. The solutions given for this problem also come up with another kind change i.e. coverage of the land by vegetation.

Changes in land use and land cover caused through direct and indirect consequences of human activities on the environment for the purpose of having better life and survival. One of the direct impacts of humans is population growth where its increase and decrease have effects on land use especially in developing world at longer time scales. According to Lambin*et al*.(2003), it can also be caused by the mutual interactions between environmental and social factors at different spatial and temporal scales as land use and land cover change is a complex process.

The impacts of LULC change were observed mainly on forest status, biodiversity, cultivated land, grazing land,climate and hydrological cycle.

It is estimated that in Ethiopia, 40 percent of the country was covered with forests at the beginning of the 19thcentury(Dudgeon, 2003). But, the forest cover was estimated to be only 4.2 percent in 1997(FAO, 2001) due to vast deforestation activities.

A major impact of land-use and land-cover is on soil and biotic resources. In Ethiopia, the loss of plant biodiversity due to the human interference in national parks and reserved forest areas is common. This problem has occurred beyond the limit of national parks and natural forests

particularly in the highlands because vegetation and soils of these areas have been affected strongly(Kahsay, 2004). The loss of biodiversity may lead to the decline of ecosystem integrity and loss of species genetic resources, which in turn affect people's way of life.

Land-use and land-cover is by far the most important determinant of erosion in the highlands of Ethiopia(Woldeamlak, 2002). The northern and central highlands of Ethiopia are relatively, unstable, compared to the south and south-western highlands. Consequently, the land use and cover pattern in northern and central highlands contribute a lot to soil loss due to erosion(Amare, 2013). The rate and severity of soil erosion and land degradation partly depends on land use pattern. The problem of soil erosion starts with the removal of land cover for various purposes.

2.7 Remote Sensing

Remote sensing is the science and art of obtaining information about an object, area, or phenomenon through the analysis of data acquired by a device that is not in contact with the object, area, or phenomenon under investigation(Lillesand*et al*., 2004). It refers to the activities of recording/observing/perceiving (sensing) objects or events at far away (remote) places. In remote sensing, the sensors are not in direct contact with the objects or events being observed. The information needs a physical carrier to travel from the objects/events to the sensors through an intervening medium. The electromagnetic radiation is normally used as an information carrier in remote sensing. The output of a remote sensing system is usually an image representing the scene being observed. A further step of image analysis and interpretation is required in order to extract useful information from the image. The human visual system is an example of a remote sensing system in this general sense.

With the invention of Remote Sensing and GIS techniques land use/cover mapping is a useful and detailed way to improve the selection of areas designed to agricultural, urban and/or industrial areas of a region(Selcuk*et al*., 2003). Application of remotely sensed data made possible to study the changes in land cover in less time, at low cost and with better accuracy(Kachhwala, 1985) in association with GIS that provides suitable platform for data analysis, update and retrieval(Star *et al*., 1997; Chilar, 2000). RS along with GIS tools used to gather, display, store, analyze and output data related to changes on environment, can provide researchers and planners with certain data sets in order to better understanding and management of a given area.

Sharma *et al*., (2013) stated as Remote Sensing data is very useful because of its synoptic view, repetitive coverage and real time data acquisition. The digital data in form of satellite imageries, therefore, enable to accurately compute various land use/land cover categories and helps in maintaining the spatial data infrastructure which is very essential for urban expansion monitoring and change detection studies.

2.8 Image Classification

In order to examine and assess environmental and socioeconomic applications such as: LULC change detection and socioeconomic variables, image classification results with better accuracy are mandatory. Image classification refers to the extraction of differentiated classes or themes, usually land cover and land use categories, from raw remotely sensed digital satellite data(Weng, 2012). Image classification using remote sensing techniques has attracted the attention of research community as the results of classification are the backbone of environmental, social and economic applications(Lu and Weng, 2007). Because image classification is generated using a remotely sensed data, there are many factors that cause difficulty to achieve a more accurate result. Some of the factors are:

- The characteristics of a study area,
- Availability of high resolution remotely sensed data,
- Ancillary and ground reference data,
- Suitable classification algorithms and the analyst's experience, and
- Time constraint.

These factors highly determine the type of classification to be used for image classification. There are various image classification methods that can be applied to extract land cover information from remotely sensed images(Lu and Weng, 2007). However, their application depends on the methodology and type of data to be used. Some of these methods are: artificial neural networks, fuzzy-sets and expert systems. In a more specified way, image classification approaches can be categorized as supervised and unsupervised, or parametric and nonparametric, or hard and soft (fuzzy) classification, or per-pixel, sub-pixel and per-field. Some of the most commonly used image classification methods are discussed below.

2.8.1. Object-Oriented Image Classification Methods

This method of image classification is based on identifying image objects, or segments with similar texture, color and tone of spatially contiguous pixels(Gao and Mas, 2008; Weng, 2012). This approach allows for consideration of shape, size, and context as well as spectral content(MacLean and Congalton, 2012). The classification stage starts by grouping the neighboring pixels into meaningful areas. Qian*et al*.(2007) noted that in object oriented classification approach, single pixels cannot be classified rather homogenous image objects are extracted during segmentation step. Image analysis in object-oriented is based on contiguous, homogeneous image regions that are generated by initial image segmentation.

2.8.2. Pixel-Based Image Classification Methods

Pixel-based classification methods automatically categorize all pixels in an image into land cover classes fundamentally based on spectral similarities(Qian*et al*, 2007; Weng, 2012). These types of classifiers develop a signature by summing up all pixels. Thus, the developed signature contains the necessary things found in the training pixels but does not contain the influence of mixed pixels(Weng, 2012). According to Tadesse*et al.* (2003), there are two primary types of pixel-based classification algorithms applied to remotely sensed data: unsupervised and supervised.

Unsupervised image classification algorithms are based on categorizing each pixel to unknown cluster centers and then moving from one cluster center to another in a way that the Supervised Spatial Encoder (SSE) measure of the preceding section is reduced data. Whereas in the case of supervised image classification the analyst has previous knowledge about pixels to generate representative parameters for each land cover class of interest. The Maximum Likelihood classification, under the category of supervised classification, which is the most widely, used per-pixel method by taking in to account spectral information of land cover classes(Qian*et al.*, 2007).

Although pixel based classification methods have been widely accepted and applicable, however, there are limitations in including spatial pattern during classification. This happened especially in Maximum Likelihood classification methods where they consider only spectral information by neglecting contextual and texture information(Zhou and Robson, 2001; Dean and Smith, 2003).

2.8.3. Contextual Image Classification Approaches

In the case of maximum likelihood classification technique the pixels are assigned to represent classes taken in to consideration and this is done through observing of each pixel. However, there could be misclassification errors especially during the presence of random noise which causes different classes to be appeared similar(Sharma and Sarkar, 1998). To avoid such problems, contextual classification techniques have been chosen which exploits spatial information among neighboring pixels. These techniques are based on the assumption that the response and class of two spatially neighboring pixels are highly related. The advantage of using contextual techniques will improve image classification results by reducing error rates related to spectral properties(Weng, 2012).

2.8.4 Post Classification Approaches

Post classification approach is based on the use of supervised classification approaches (requiring an a prioriknowledge of data classes), and it is based on texture features. The extraction of texture features cannot be done at pixel level, because the texture is defined on a set of pixels(Hicham*et al*., 2007). This method is the most simple and obvious change detection based on the comparison of independently classified images(Singh, 1989). Maps of changes can be produced by the researcher which shows a complete matrix of changes from times t_1 to time t_2. Based on this matrix, if the corresponding pixels have the same category label, the pixel has not been changed, or else the pixel has been changed(Xu*et al*., 2009).

2.9 Change Detection Analysis

Change detection can be defined as the process of identifying differences in the state of object or phenomena by observing them at different times by using remote sensing techniques. Essentially, it also involves the ability to quantify temporal applications of remotely-sensed data obtained from Earth-orbiting satellites(Singh, 1989).

As indicated from the beginning of this chapter there are four aspects of change detection which areimportant when monitoring natural resources:

i. Detecting the changes that have occurred

ii. Identifying the nature of the change

iii. Measuring the area extent of the change

iv. Assessing the spatial pattern of the change

Change detection has a wide range of applications in different disciplines such as land use change analysis, forest management, vegetation phenology, seasonal changes in pasture production, risk assessment and other environmental changes(Singh, 1989). The main objective of change detection is to compare spatial representation of two points in time frame by controlling all the variances due to differences in non-target variables and to quantify the changes due to differences in the variables of interest(Lu *et al*, 2004). A change detection research to be good, it should provide the following vital information: area change and rate of changes, spatial distribution of changed types, change trajectories of land-cover types and accuracy assessment of change detection results.

Quantifying land use and land cover changes and applying suitable change detection methods highly depend on the type of changes that happened in landscapes and how those changes are noticeable in images. The changes could be continuous or categorical. According to Abuelgasim*et al.*(1999), change detection in continuous land cover changes focuses on measuring the degree of changes in amount or concentration through time. However, in the case of categorical land cover changes, the goal of change detection is to identify new land cover classes and changes between classes through time.

2.10 Geographic Information System

Maps have been used for thousands of years, but it is only within the last few decades that the technology has existed to combine maps with computer graphics and databases to create geographic information systems(GIS). Many GIS databases consist of sets of information called layers. Each layer represents a particular type of geographic data. For example, one layer may include information on the streets in an area. Another layer may contain information on the soil in that area, while another records elevation. The GIS can combine these layers into one image, showing how the streets, soil, and elevation relate to one another.

A GIS database can include as many as hundred layers. This capability of GIS makes it a very useful tool in the analysis of land use changes. Layers for land use change analysis can be datasets obtained at different periods, different classes of land use at the same period, drivers of land use change etc. The applications of a GIS are vast and continue to grow. By using a GIS, scientists can research changes in the environment; engineers can design road systems; electrical

companies can manage their complex networks of power lines; governments can track the uses of land, make policies to guide the use of land for a sustainable environment; fire and police departments can plan emergency routes.

Computerized mapping and spatial analysis have been developed simultaneously in several related fields. The present status would not have been achieved without close interaction between various fields such as utility networks, cadastral mapping, topographic mapping, thematic cartography, surveying and photogrammetry, remote sensing, image processing, computer science, rural and urban planning, earth science, and geography. The GIS technology is rapidly becoming a standard tool for management of natural resources. The effective use of large spatial data volumes is dependent upon the existence of an efficient geographic handling and processing system to transform this data into usable information.

The GIS technology is employed to assist decision-makers by indicating various alternatives in development and conservation planning and by modeling the potential outcomes of a series of scenarios. It should be noted that any task begins and ends with the real world. Data are collected about the real world. After the data are analyzed, information is compiled for decision-makers. Based on this information, actions are taken and plans implemented in the real world.

2.11Marcov Chain Model

Markov chain models are relatively simple and more powerful to model complex processes and changes in land use for planning purposes. They provide better information for analyzing time series of system evolution(Levinson and Chen, 2005). A Markovian process is one in which the state of a system at time t_2 can be predicted by the state of the system at time $t_1$given a matrix of transition probabilities from each cover class to every other cover class.

A stationary property is one of the importances of this model since it integrates a transition probability matrix. This property is critical to Markov chain model especially for future predictions of land use. The stationary of the transition matrix in turn helps to inspect the validity of the model(Iaconoet *al.*, 2012). The Marcov module in IDRISI can be used to create such a transition probability matrix(Eastman, 2012).

Markov Chain model to be considered as a system, it has to satisfy the following properties:

- The sum of the rows of the probability matrix must be one
- The probabilities of the transition matrix must be the same for any two periods

- Probabilities have no memory, that is, the state tomorrow depends only on the state today (the Markov condition)
- Time periods must be uniform in length or duration.

Markov chain model has a good quality of simplicity. It can also describe complex and long-term process of land use conversion in terms of simple transition probabilities.

The advantages of Markov chain model may be summarized as follows.

i. Markov models are relatively easy to derive (or infer) from successional data.
ii. The Markov model does not require deep insight into the mechanisms of dynamic change, but it can help to indicate areas where such insight would be valuable and hence act as both a guide and stimulant to further research.
iii. The basic transition matrix summarizes the essential parameters of dynamic change in a way that is achieved by very few other types of model.
iv. The results of the analysis of Markov models are readily adaptable to graphical presentation and, in this form, are frequently more readily presented to, and understood by, resource managers and decision makers.
v. The computational requirements of Markov models are modest, and can easily be met by small computers, or, for small numbers of states, by simple calculators.

The disadvantages of Markov chain model are also summarized as follows.

i. The lack of dependence on functional mechanisms reduces their appeal to the functionally orientated ecologist.
ii. Departure from the simple assumptions of stationary, first-order Markov chains while, conceptually possible, makes for disproportionate degrees of difficulty in analysis and computation.
iii. In some areas, the data available will be insufficient to estimate reliable probability or transfer rates, especially for rare transitions. For example, it may not be possible to observe sufficient transitions from a given transient set of states to a closed state where this transition is dependent on a rare climatic event, even though the value of this parameter is of vital importance in the dynamics of the community.
iv. Like all other successional models, the validation of Markov models depends on predictions of system behavior over time, and is therefore frequently difficult, and may even be impossible, for really long periods of time.

These difficulties warrant a high degree of caution in the uncritical use of Markov model in ecology. Of the disadvantages listed, the second is perhaps of the greatest significance because it is doubtful whether most ecological successions do, in fact, have homogeneous transition matrices that are constant in time. A constant transition probability implies that the future behavior of a system is determined only by its present state and is independent of the way in which this state has developed(http://www.scopenvironment.org).

CHAPTER THREE

3. DATA AND METHDOLOGY

3.1 Description of the Study Area

3.1.1 Location of the Study Area

FagitaLekomaWoreda is located between10°57’23’’-11°11’21’’North latitude and 36°40’01’’-37°05’21’’ Eastlongitude, in AwiZone ofAmhara National Regional State(ANRS). The Woredacoversa total area of 65,579ha. It is situated about 460 kilometers northwest of Addis Ababa and 100kilometers southwest ofBahir Dar, the capital city of ANRS.

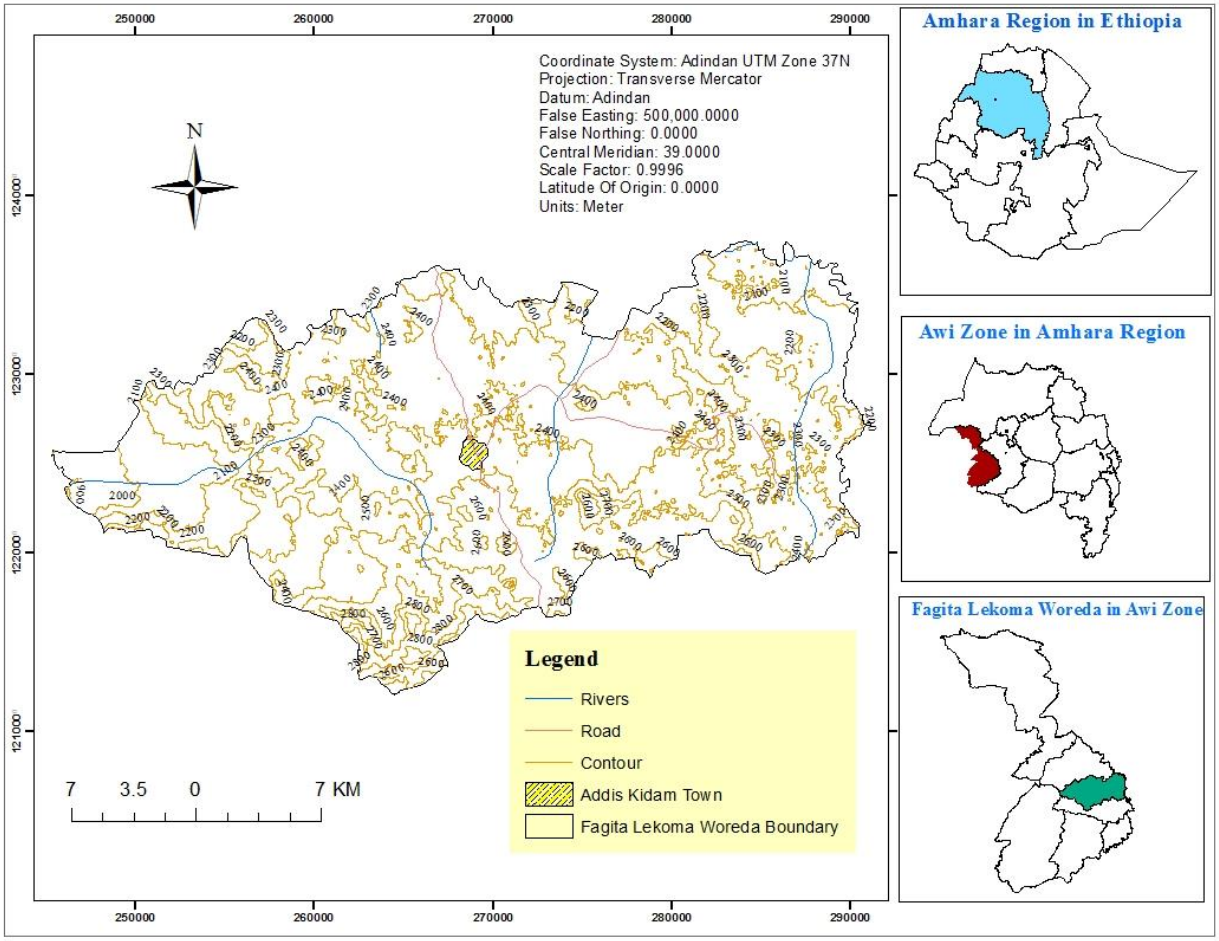


Fig. 3.1 Map of the Study Area*(Source: CSA, 2007)*

3.1.2 Physiographic Nature of the Study Area

The regional geology of the woreda is dominated by the Tertiary volcanic rock and Quaternary Basalts. The relief type consists of 62% plain, 23% mountains, and 15% others. The major soil types include Vertisols, Nitosols, and Cambisols. Generally, the soils types of the study area are characterized with shallow, moderate to deep and very deep in depth and sandy clay to clay texture types. The erodibility of these soils also varies from medium to very erodible characteristics(FLWARDO, 2014).

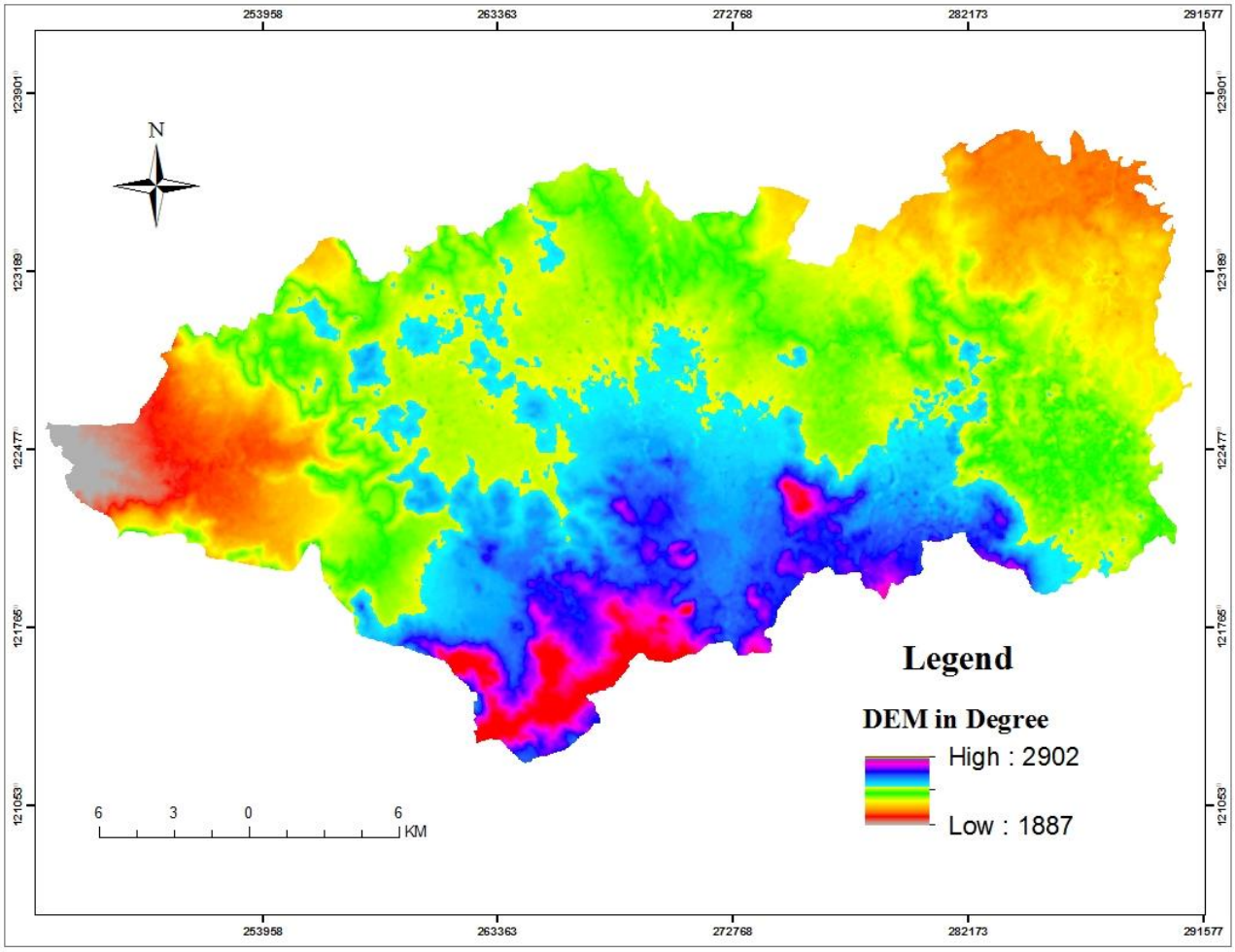


Fig.3.2 DEM Map of FagitaLekomaWoreda*(Source: Post Graduate GIS Lab.)*

Climatic conditions in FagitaLekoma are divided into two agro-climatic zones namely Dega(highland with 2500-3000m altitude) 16% and Weynadega(midland with 1500-2500m altitude) 84%. The altitudinal variation of the study area generally ranges from 1887-2902 m above sea level(Fig. 3.2).

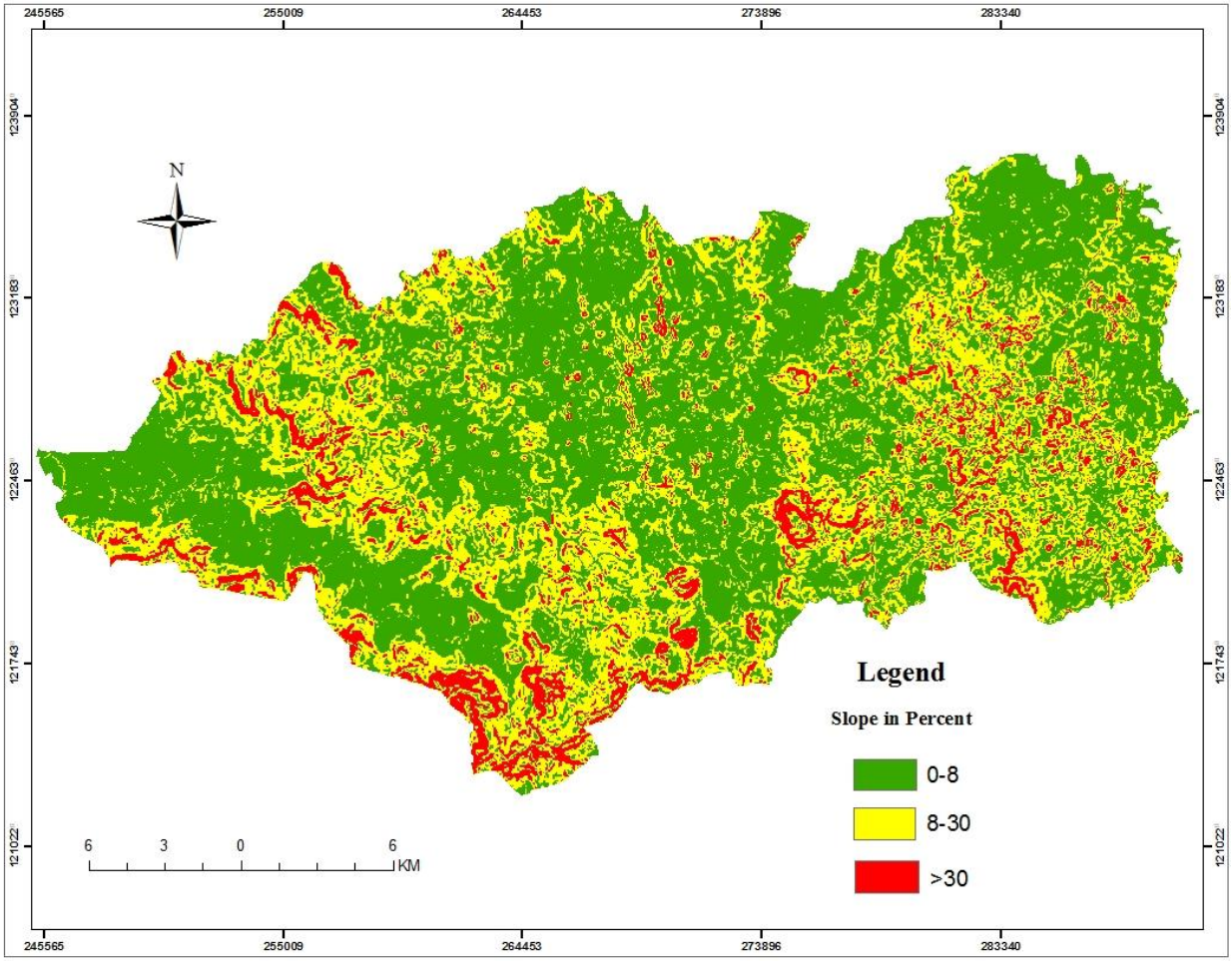


Fig.3.3Slope Map of FagitaLekomaWoreda*(Source: Generated from DEM)*

Temperature varies between the mean annual maximum of 25°C and mean annual minimum of 11°C across the elevation gradient. Average annual rainfall is 2379 mm with unimodal rainy season.

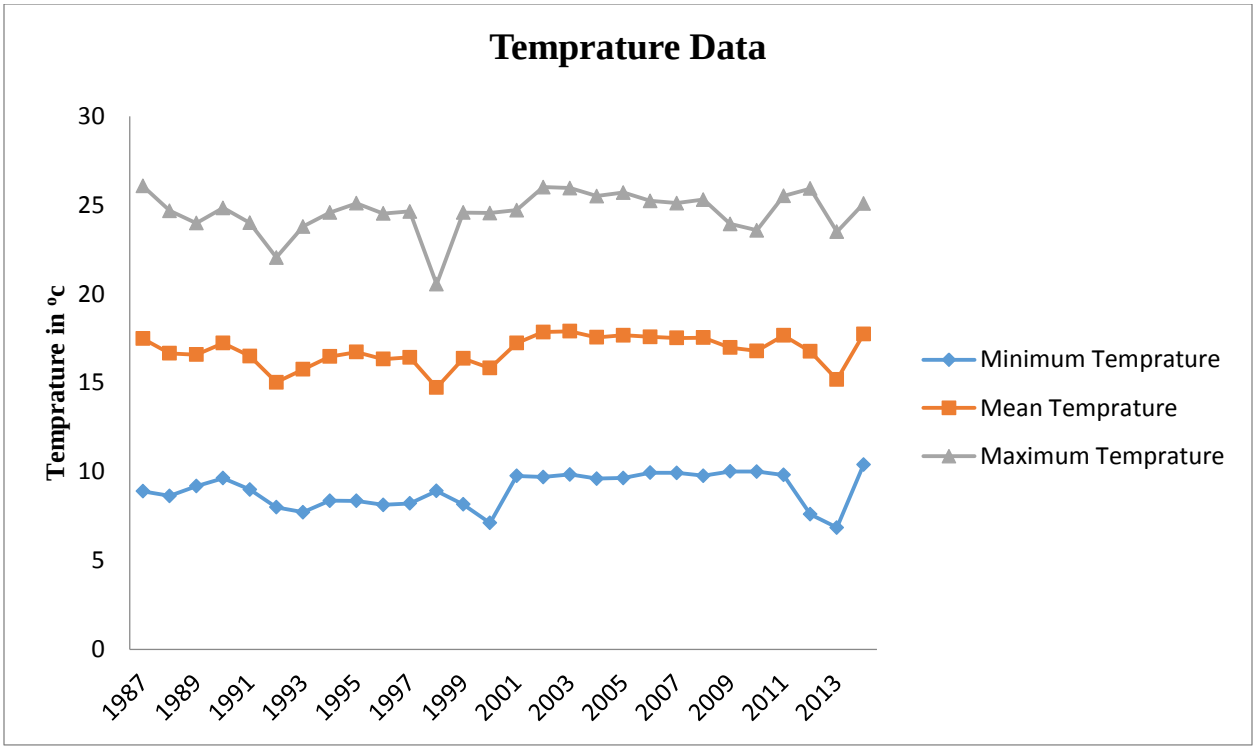


Fig. 3.4 Temperature Data of the Study Area(*Source: National Meteorological Agency)*

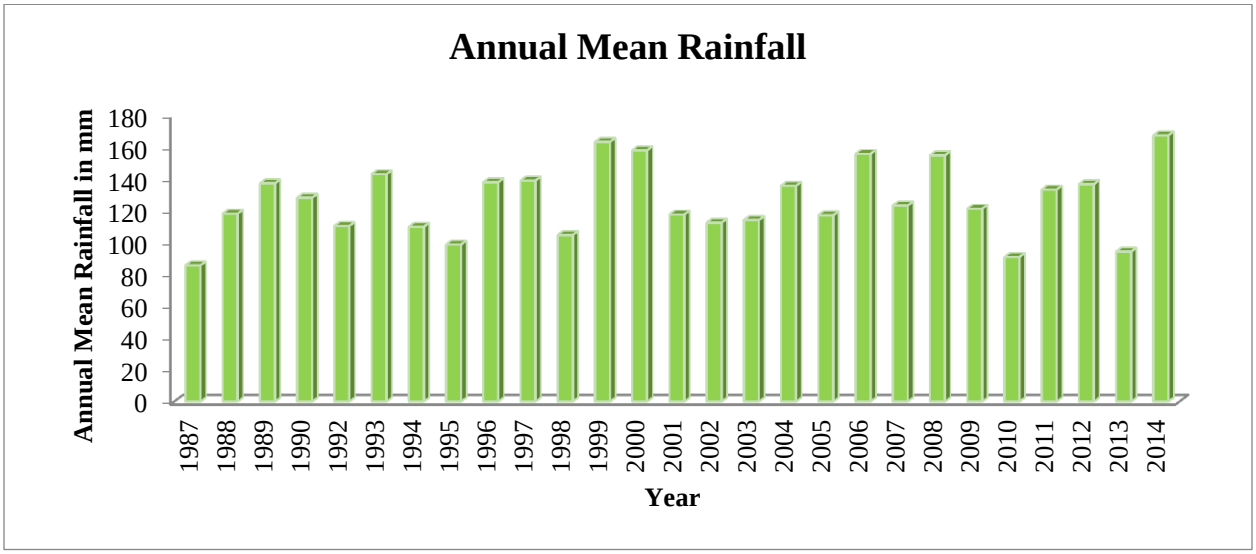


Fig. 3.5 Rainfall of the Study Area(*Source: National Meteorological Agency*)

The rainy season for the area is from beginning of June to end of September. The farming system is a mixed agriculture under rain-fed farming system supplemented with traditional irrigation. Irrigation facilities are limited to few locations depending upon the availability of suitable sites for traditional irrigation. The maximum irrigation is available in one of the kebelecalled *Nechelakebele*due to availability of perennial streams and suitably the water is diverted to nearby fields (FLWARDO, 2014). The major annual crops grown in the study area are barley, potato,teff, wheat, maize and noug. The natural vegetation is shrunk at the borders of Banjaand GuanguaWoredasand around the Churches only as they are not damaged due to religious considerations. But the amount of manmade vegetation is increasing in alarming rate from time to time. For example, around 18 million and 33 million seedlings were grown in 2013 and 2014 years which covered almost 900ha and 17,500ha respectively.

3.1.3 Population

The first national population and housing census was conducted in 1984 and the population of FagitaLekomaWoreda was 53,552. After 10 years in 1994, the second census has also been conducted and the total population was 97,446 with an increase of about 81.97% from 1984. In 2007, the total population has become 126,367. The value increased by about 29.68% of the population of 1994 according to the CSA.

Table 3.1 Total Population of FagitaLekoma Woreda1984-20014 (*Source: CSA*)

Year	**Total Population**
1984	53,552
1994	97,446
2007	126,367

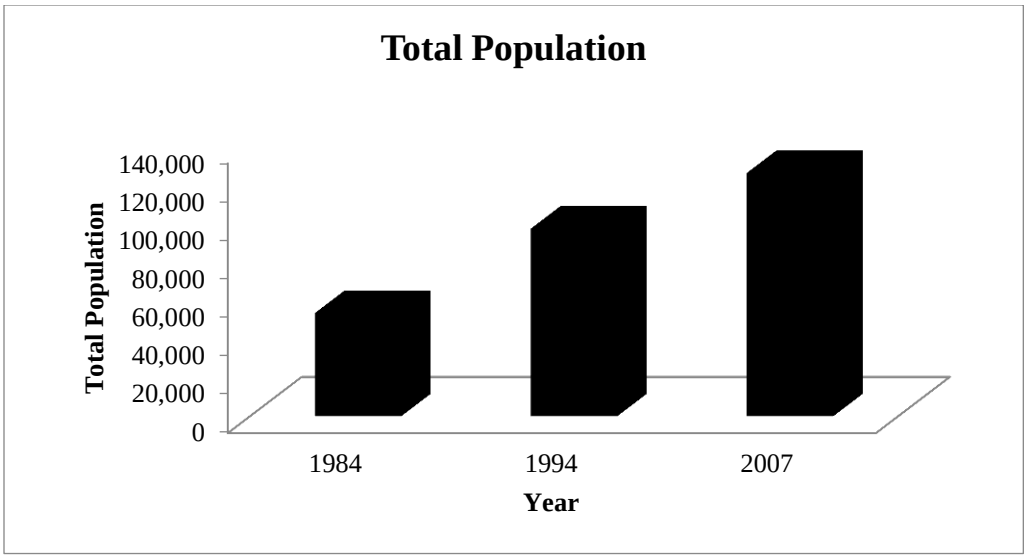


Fig. 3.6 Total Population of FagitaLekomaWoreda*(Source: CSA)*

3.2 Data Acquisition and Source

This study involved primary and secondary data collectiontechniques. Landsat satellite images of the study area were acquired for three periods; 1973, 1987 and 2015. These images were obtained from United States Geological Survey(USGS). The images were extracted to Tiff formats for processing and the detail of image properties are summarized in table 3.2 below. The images were acquired from the period January–February, as this is a clear sky season in the region, reducing atmospheric and radiometric problems.

Images were composed in different ways in order to identify surface features in the study area. True color composite usually known by RGB 321 combination where band 3 reflects red color, band 2 reflects green and band 1 reflects blue color. Another composite called "false color composite" which uses an RGB combination of 432. In this band combination band 4 represents the NIR infrared, band 3 belongs to red and band 2 to green. This combination gives better visualization in identifying vegetation which looks red in 432 combinations. Figure 3.3 below illustrated maps of the study area generated using the false color combination and vegetation is seen as red and dark red, water is blue and shades of blue.

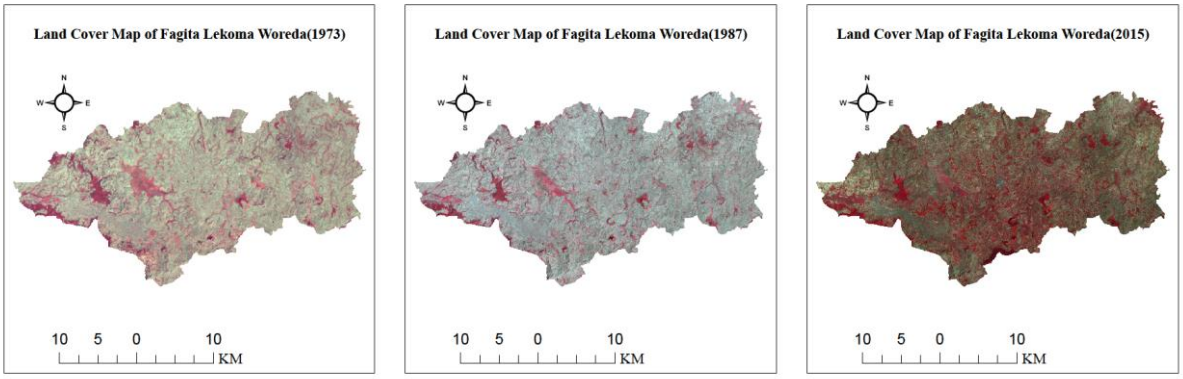


Fig. 3.7 False Color Composite of 1973(left), 1987(middle) and 2015(right)

The local administrative data and topographic map of the study area were obtained from CSA and Ethiopian Mapping Agency(EMA) respectively. These were brought to Universal Transverse Mercator(UTM) projection in zone 37N.

Table 3.2 Data Source Characteristics

No.	Data Type	Sensor	Date of Acquisition	Path/Raw	Resolution	Source
1	Landsat Image	MSS	01/2/1973	182&183/52	60m by 60m	USGS
2	Landsat Image	TM	9/2/1987	170/52	30m by 30m	USGS
3	Landsat Image	ETM+	20/2/2015	170/52	30m by 30m	USGS

Then field visits to site was carried out to obtain ground control points using *etrix*-30 Garmin GPS for ground truth sampling.

To perform the classification the maximum likelihood supervised classifier is employed. Training areas for all spectral classes were developed composing each information class to be identified by the classifier. Since there was more than one spectrally different signature found for each information class. For example, an information class such as cultivated land contains several crop types, active agriculture and inactive agriculture areas, and each of them must be

represented by several spectral classes. The researcher used more than thirty training samples for each classification. A recode function was used to merge spectrally different classes to generate final information classes. Landsat multispectral bands, except the thermal band, were used to identify the classes.

The post-classification approach was used for mapping detailed LULC determination. This approach is generally considered the most obvious approach to change detection(Liu and Zhou, 2004). It requires the comparison of independently classified images of the same study area acquired over two different time periods(Serra *et al*., 2003). Originally used for Landsat change detection in the late 1970s, this approach was considered the most reliable and was used as a standard for quantitative evaluation of emerging image differencing techniques(Soe and Le, 2006). By properly coding the classification results for times 1974, 1987 and 2015, the analysis were produced a change map showing a complete matrix of changes(e.g., change from wetland to cultivated land and grassland to forest).

One advantage of using post-classification change detection is that data normalization for atmospheric and sensor differences between two dates is not required, since images acquired for two dates are classified separately(Singh, 1989).

The principal advantage of post classification comparison lies in the fact that the two dates of imagery are separately classified; thereby minimizing the problem of radiometric calibration between dates(Copping, 2004). If the same type of satellite imagery for two different periods of time that are necessary to achieve a particular objective set in a project is lacking and two completely different but similar or comparable satellite data are available, this approach can be effectively used because classification is done independently. This is the case for most projects that examine change over a longer duration between two time periods and one type of remotely sensed data is not available for both dates. The important issue to be considered in this study is the spatial resolution of two different Landsat images (e.g., 60m MSS data and 30m TM data). For these reasons, the researcher employed the post-classification change detection approach.

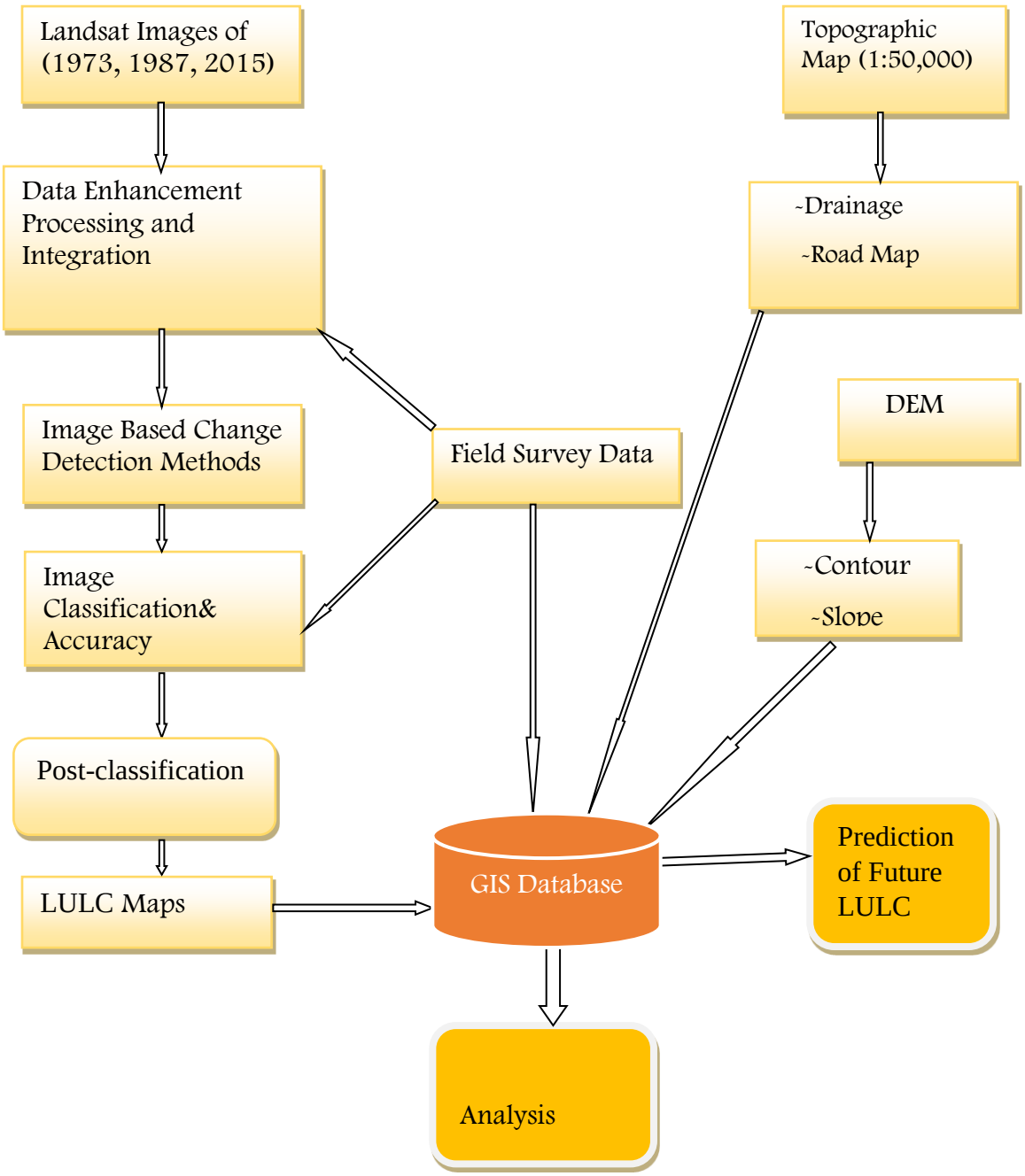


Fig. 3.8 General Procedure of the Study

3.3 Development of a Classification Scheme

Based on the prior knowledge of the study area and a brief reconnaissance survey with additional information from elders, a classification scheme is developed for the study area as fallow:

Cultivated land: This category includes area allotted for annual rainfed and irrigated cultivation. Lands mostly used for cereal production in subsistence farming and mixed with bushes like *Avalo* (*Combretummolle*) and trees like *Qoba (Mytenusarbutifolia)* are the common character of cultivated lands in this category.

Grassland: Area predominantly covered by small grasses with a small proportion of shrub and trees like *Qoba (Mytenusarbutifolia)* and *Avalo* (*Combretummolle*). Usually this category is used for grazing.

Wetland: Represents most plains areas with frequent flooding event during the rainy season and water table is at, near, or above the land surface for a significant part of most years. The category includes one of the great swampy areas called *Zimbiri* which is located west of Addis Kidam town.

Forest: This unit includes densely growth trees forming closed canopy. The predominant species are *NechBahirzaf* (*Eucalyptus globules*), *Chigegn* (*Acacia decurrens*),*Injory*(*Morusmesozygia*),*Qoba (Mytenusarbutifolia)*and *Kerkeha* (*Arundinaria alpine*) or Bamboo forest.

Urban settlements: Area occupied by small town including market places, roads institution such as school, clinic, court and others.

The definitions of LULC types given above are a modification of Anderson's classification scheme in 1976.

3.4 Accuracy Assessment

Accuracy assessment is the comparison of a classification with ground truth data to evaluate how well the classification represents the real world. It is performed by comparing a map created by using remote sensing analysis to a reference map based on different information sources such as field survey, Google Earth and original mosaic images. An interpretation is then made of how close the newly produced map from the remotely-sensed data matches the reference (source) map. Although the basic approaches to accuracy assessment seems relatively direct and easy, a variety of errors encountered when evaluating an image classification and capturing remotely

sensed data. Evaluation of the accuracy of a classified image can be done using an error matrix sometimes called confusion matrix(Sensemane*t al*, 1995; Foody, 2002).

Error Matrix is a square array of numbers laid out in rows and columns that express the number of sample units assigned to a particular category relative to the actual category as verified in the field. The columns normally represent the reference data, while the rows indicate the classification generated from classified image. It also provides an excellent summary of the two types of thematic error that can occur, namely, omission and commission. Error of omission refers to pixels in the reference map that were identified as something other than their "accepted" value. Whereas error of commission, on the other hand refers to pixels that were incorrectly classified as a class in a row(Maingi*et al*, 2002).

Most of the classification accuracy measurements are derived from an error matrix. However, the most popular one is the correctly allocated cases in a percentage. Based on this, user's accuracy refers to the probability that a given pixel can be found in the ground as it is in the classified image, whereas producer's accuracy refers to the percentage of a given class that is correctly identified on the map(Yesserie, 2009).

In this study, a total test samples of 260 for image 1973, 152 for image 1987 and 190 for image 2015 were randomly selected respectively from the original mosaic images of 1973and 1987 and Google earth for the images 2015. In addition for 1973 and 1987 images some of the sample points were supported by local area elders as "what was there at what time" and for 2015 visual observations was carried out. The researcher has examined the test sample plots and assigned a class value to each. The accuracy assessment was conducted for each classification result. Thus, agreement and disagreement of the analysis is evaluated by using an error matrix and Kappa coefficient results.

3.5 Methods of Data Analysis

Three main methods of data analysis were adopted in this study.

(i) Calculation of the area in hectare and percent of the resulting LULC types for each study year and subsequently comparing the results.

(ii) Overlay Operations

(iii) Markov Chain for predicting change

The first two methods above were used for identifying change in the land use types. Therefore, they have been combined in this study.

The comparison of the LULC statistics assisted in identifying the percentage change, trend and rate of change between 1973 and 2015. In achieving this, the first task was to develop a table showing the area in hectares and the percentage change for each year (1973, 1987 and 2015) measured against each LULC type. Percentage change to determine the trend of change can then be calculated by dividing observed change by sum of changes multiplied by 100.

$$\text{percentage change(trend)} = \frac{observed\ change}{sum\ of\ change} * 100$$

In obtaining annual rate of change, the percentage change observed in the study period is divided by the number of years in the study period i.e. 1973 – 1987 (14years) and 1987 – 2015 (28years). Going by the third method Markov Chain Analysis, which is a convenient tool for modeling land use change when changes and processes in the landscape are difficult to describe. According to Estman(1995), a Markovian process is one in which the future state of a system can be modeled purely on the basis of the immediately preceding state. Markovian chain analysis will describe land use change from one period to another and use this as the basis to project future changes. This is achieved by developing a transition probability matrix of land use change from time one to time two, which shows the nature of change while still serving as the basis for projecting to a later time period. The transition probability may be accurate on a per category basis, but there is no knowledge of the spatial distribution of occurrences within each land use category.

3.6 Software Used

Basically, the followingsoftwares were used for this project;

(a) **ERDAS Imagine 2010** – this was used for displaying and subsequent processing and enhancement of the image. It was also used for the carving out of the study area from the whole scene imagery using administrative boundary data. The land LULC classes were also developed using this software.

(b) **ArcGIS 10.2** – This was also used to compliment the display and processing of the data. This was also used for change detection analysis of the study area.

(c) Other's **Microsoft Word 2010 and Microsoft Excel 2010**.

CHAPTER FOUR

4. RESULTS AND DISCUSSIONS

4.1 Land Use/Land Cover Dynamics

As indicated in the classification scheme **cultivated land**, **grassland**, **wetland**, **forest** and **urban area** are the major LULC classes for the study periods.The classified images were acquired, when crop harvesting had already started, and farmlands appear bare and grasslands look relatively bright in their color. Regarding vegetation, there were relatively undisturbed areas that had been serving as a home for some wild animals with varying levels of density, ground cover and disturbance. Some of these forests have been sources of wood for house construction, household energy andfarm implements.

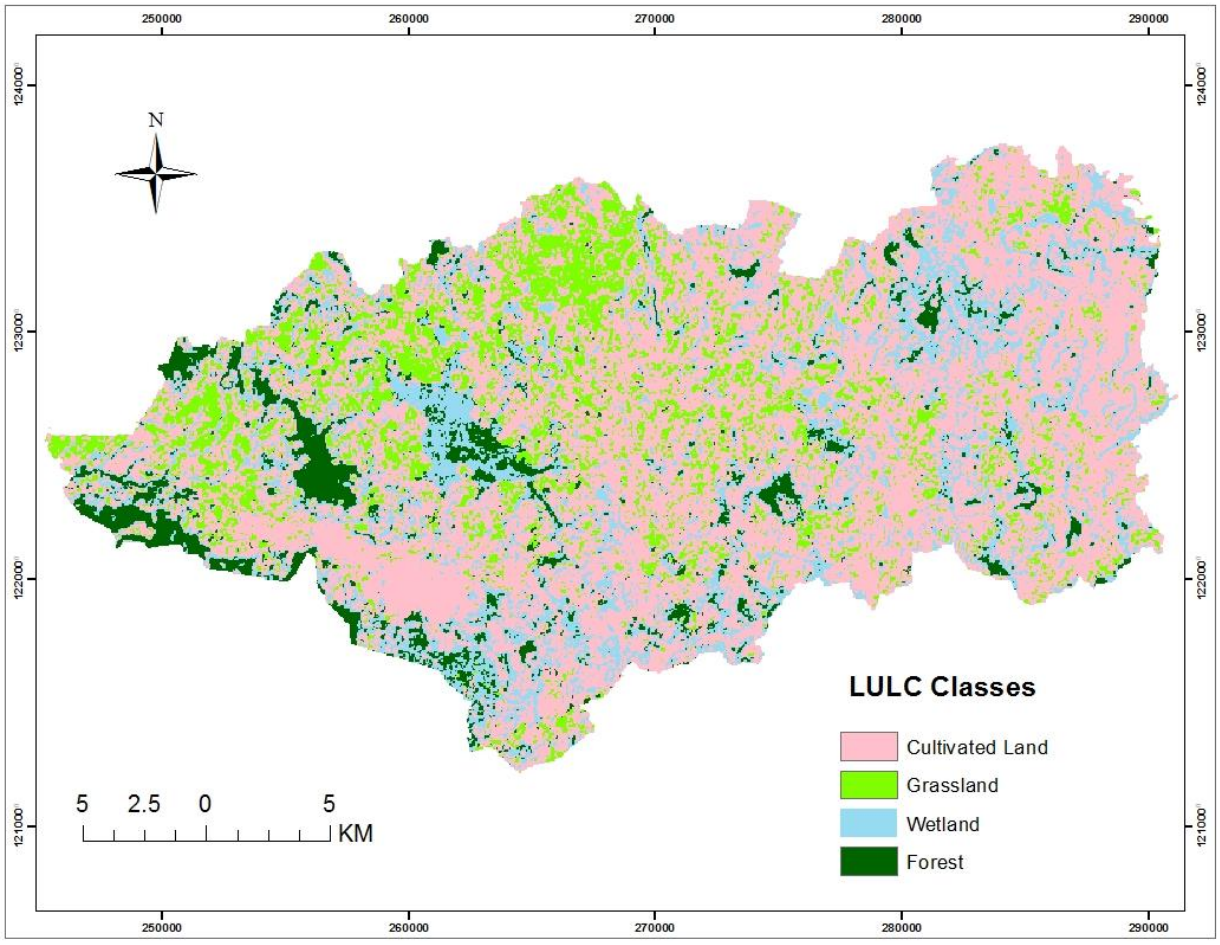


Fig. 4.1 LULC Map of FagitaLekomaWoreda in 1973

The classification result of the 1973 image revealed that cultivated land constituted the largest proportion of land in the woreda with a value of 58.3%, followed by wetland which accounts for 18.6 % (Figure 4.1). Grassland and forest constituted 15.8% and 7.3% respectively. But there was no urban area during this time. In Ethiopia, before 1974, the relationship between land users and owners was based on a feudal system (Lakew et al., 2000) under which the ownership of land was limited to a few individuals. Most inhabitants were only eligible to get access to farmland through share cropping. According to the eldersduring this period, it was highly likely that a portion of the land was left abandoned. Human population in the woredawas relatively low with low pressure on the land and associated resources.

Table 4.1 LULC Class Distributions of FagitaLekomaWoreda

No.	**LULC Class**	**Year**		
		1973	**1987**	**2015**
1	Cultivated Land	58.3%	62.8%	56.5%
2	Grassland	15.8%	32.3%	22.7 %
3	Wetland	18.6%	1%	0.2%
4	Forest	7.3%	3.9%	18.5%
5	Urban Area	_	_	2.1%
Total		100	100	100

As shown in Figure 4.2 for the 1987 image of the woreda, the proportion of land allocated for cultivation increased to 62.8%. Furthermore, grassland expanded and covered 32.3% of the landscape. However, the proportions of forest and wetland have decreased to 3.9% and 1% respectively.

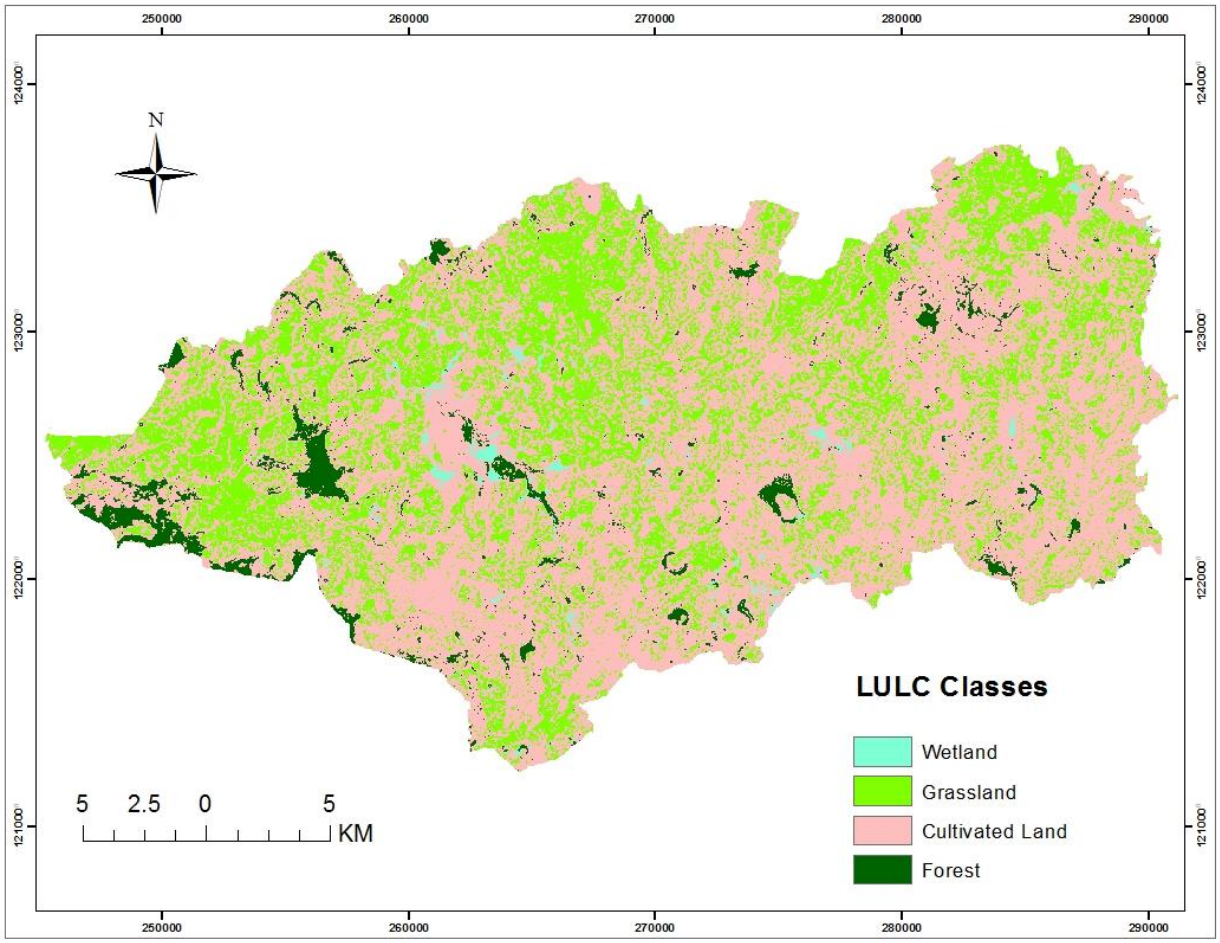


Fig. 4.2 LULC Map of FagitaLekomaWoreda in 1987

Even if there is some decrement from the amount of 1987, the cultivated land which covers 56.5% of the landscape is the dominant class again in 2015. Similarly, grassland decreased to 22.7 %. As a result the forest coverage isincreased to 18.5% and urban area which was not found on the previous classified images accounts 2.1%.Wetlands became only 0.2% of the woreda's coverage due to the dry up of the area as indicated on Figure 4.3 bellow.

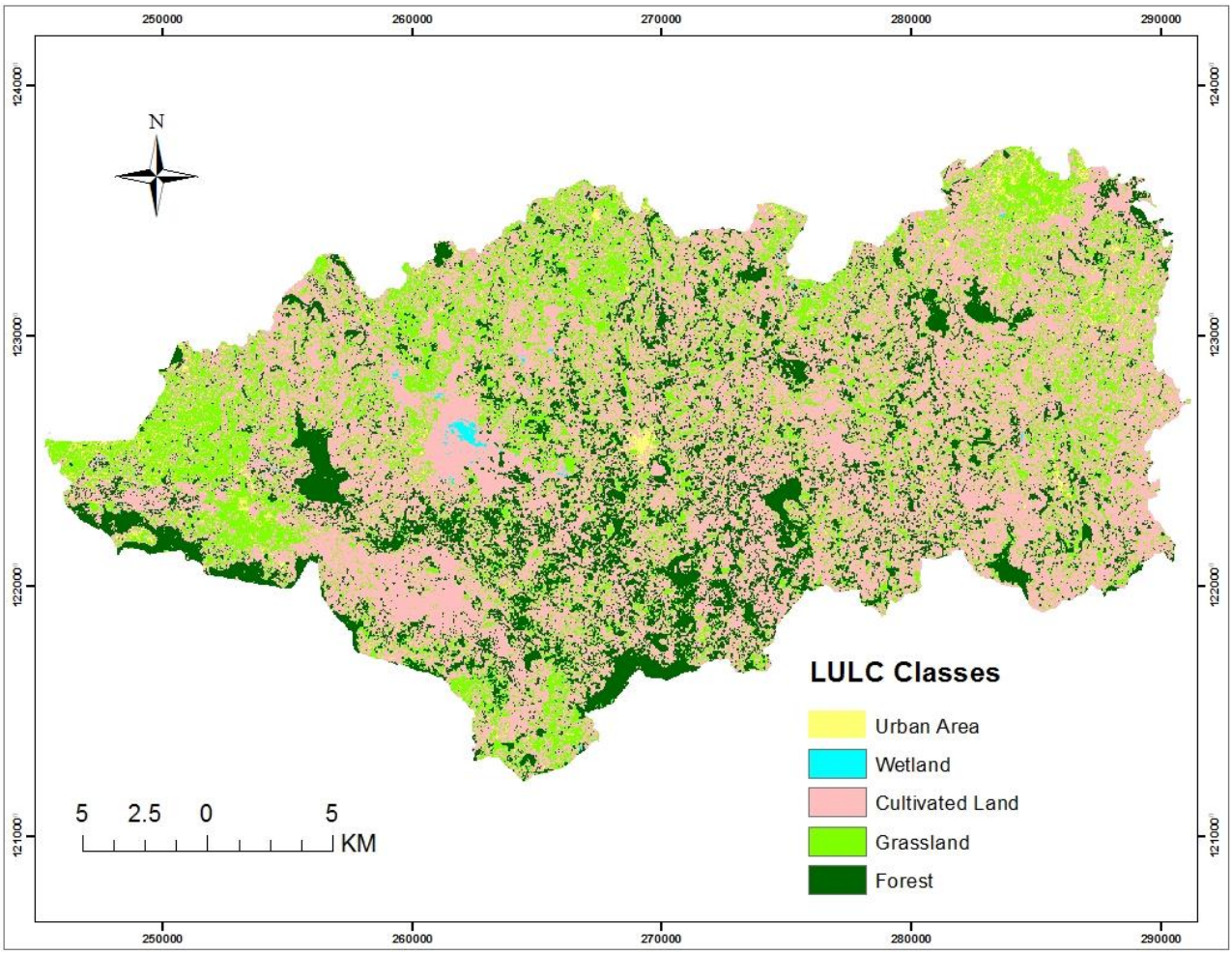
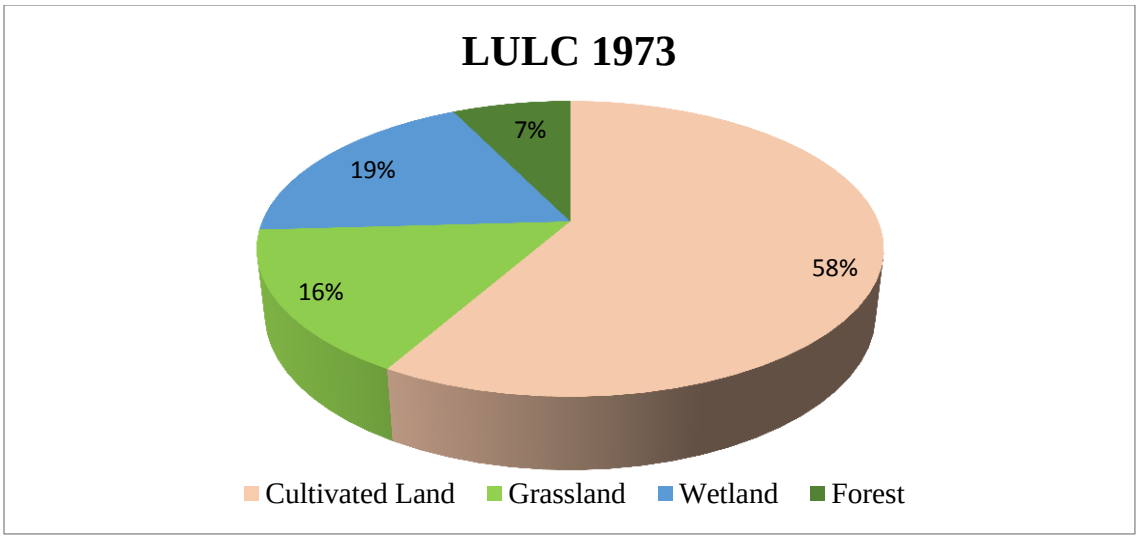
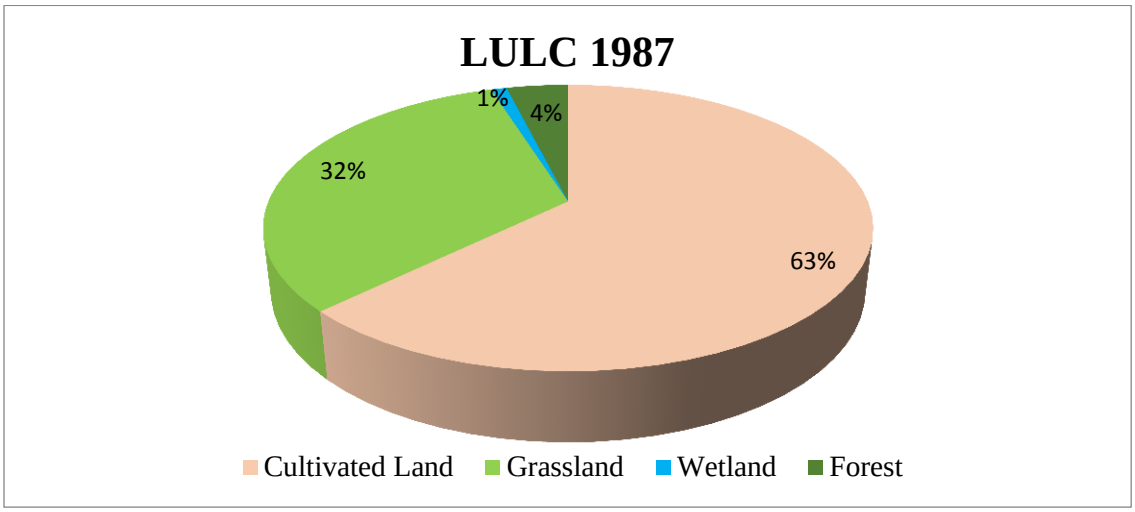


Fig. 4.3 LULC Map of FagitaLekomaWoreda in 2015





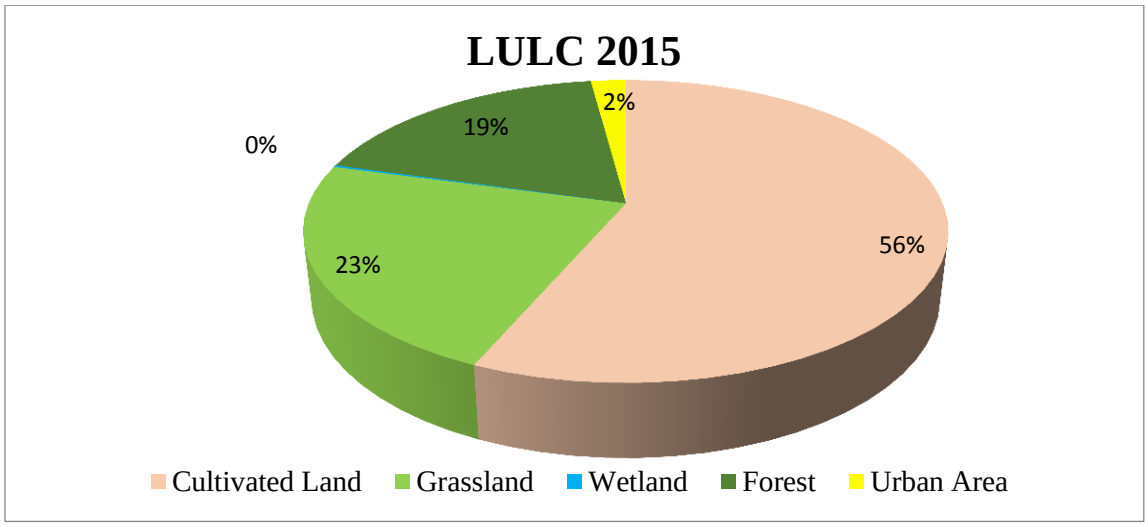


Fig. 4.4 Graphical Representation of LULC Classes for the Study Years

4.2 Accuracy Assessment of the Classification

Classified LULC maps from remotely sensed images may contain various types of errors.So accuracy assessment was appliedto find out those errors to make the produced LULC maps reliable and easily interpretable by users. Once the classified image is integrated into a GIS, accuracy assessment should be processed as it limits the classification results of a remotely sensed imagery data. To do so, the accuracy of a classified map has to be assessed and compared with a referenced data using an error matrix. The accuracy assessment in this study was made using the original images and elders who live in the study area for 1973and 1987 and field observationand Google Earth imagefor the 2015study period.

4.2.1 User's Accuracy

Users accuracy refers to the number of correctly classified pixels in each class (category) divided by the total number of pixels that were classified in that category of the classified image (row total). It represents the probability that a pixel classified into a given category actually represents that category on the ground.

Results of user's accuracy in this study showed that in 1973 the maximum class accuracy was 98.2%, which was forest where correctly classified and the minimum was cultivated land class with an accuracy of 82.4% as presented in table 4.2 below. In 1987, the class accuracies range from 76.7% to 92.1% where as in the period 2015, it ranges from 77.4% to 92.9% as indicated in tables 4.3 and 4.4 respectively. The lowest values of class accuracies were misclassified due to spectral property similarities among other land cover classes. As shown in tables 4.2 and 4.4, the user's accuracy was lowest for cultivated land as some of the agricultural areas were misclassified as wetland, forest and grassland. Moreover, the time of image acquisition has a great role for such misclassification problems. Since the images obtained during the dry season where most irrigation activities were carried out in the study area, other land cover classes appear as agriculture and vice versa.

4.2.2 Producer's Accuracy

Producer's accuracy refers to the number of correctly classified pixels in each class (category) divided by the total number of pixels in the reference data to be of that category (column total). This value represents how well reference pixels of the ground cover type are classified.

As shown in table 4.2, grasslands were largely misclassified with accuracy of81.1% and in table 4.3; also this class became a low accuracy of 74.5% whereas wetlands had been relatively properly classified. The lowest values for grassland areas in table 4.2 and 4.3 were misclassified due to the similar spectral properties of different land cover classes such as cultivated land.

Table 4.2 Confusion Matrix for the LULC Map of 1973

		Reference Data					
	Classes	Forest	Wetland	Cultivated Land	Grassland	RawTotal	Users Accuracy (%)
Classified Image	Forest	**55**	1	0	0	56	**98.2**
	Wetland	9	**49**	1	0	59	**83**
	Cultivated Land	0	3	**70**	12	85	**82.4**
	Grassland	0	0	6	**54**	60	**90**
	Column Total	64	53	77	66	260	
	Producers Accuracy (%)	**85.9**	**92.5**	**90.9**	**81.1**		
	Overall Accuracy (%)				**87.7**		

Table 4.3 Confusion Matrix for the LULC Map of 1987

		Reference Data					
	Classes	Forest	Wetland	Cultivated Land	Grassland	Raw Total	Users Accuracy (%)
Classified Image	Forest	**23**	0	0	7	30	**76.7**
	Wetland	3	**31**	1	0	35	**88.6**
	Cultivated Land	0	0	**44**	5	49	**89.8**
	Grassland	0	1	235	**38**	38	**92.1**
	Column Total	26	32	46	47	152	
	Producers Accu.(%)	**88.5**	**96.9**	**95.7**	**74.5**		
	Overall				**90.1**		

Accu.(%)							

Table 4.4 Confusion Matrix for the LULC Map of 2015

		Reference Data						
	Classes	Forest	Wetland	Cultivated Land	Grassland	Urban Area	Raw Total	Users Accuracy (%)
Classified Image	Forest	**38**	0	3	0	0	41	**92.3**
	Wetland	0	**26**	2	0	0	28	**92.9**
	Cultivated Land	4	2	**42**	1	1	50	**84**
	Grassland	0	0	2	**37**	1	40	**92.5**
	Urban Area	0	0	3	4	**24**	31	**77.4**
	Column Total	42	28	52	42	26	190	
	Producers Accuracy (%)	**90.5**	**92.9**	**80.8**	**88**	**92.3**		
	Overall Accuracy (%)				**87.9**			

4.2.3. Overall Accuracy

It is computed by dividing the total number of correctly classified pixels (i.e., the sum of the elements along the major diagonal) by the total number of reference pixels. It shows an overall result of the tabular error matrix. The overall accuracy performed in the study period 1973 was 87.7% (table 4.2), in 1987 was 90.1% (table 4.3) and during 2015 it was 87.9 % (table 4.4). As mentioned by Anderson *et al*.(1976) for a reliable land cover classification, the minimum overall accuracy value computed from an error matrix should be 85%. Therefore, the overall accuracies for the study period maps were above 85% based on Anderson's criteria.

The 1973 supervised classification with an overall accuracy of 87.7 was achieved with a Kappa coefficient (K_{hat}) of 0.8348. This value implies a strong agreement with good accuracy, and is often multiplied by 100 to give a percentage measure of classification accuracy.

Therefore, the K_{hat} value of 0.8348 represents a probable 83% better accuracy than if the classification resulted from a random assignment. The K_{hat}result of1987 and 2015 classified images are 0.8583 and 0.8467 respectively, which implies as the results are acceptable.

4.3 Land Use/Land Cover Change: Trend, Rate and Magnitude

An important aspect of change detection is to determine what is actually changing to what i.e. which land use class is changing to which other classes. This information reveals both the changes (additions and reductions) and classes that are relatively stable overtime. This information will also serve as a vital tool in management decisions. This process involves a pixel to pixel comparison of the study year images through overlays.

The assigned LULC classes during supervised classification on ERDAS Imagine were reclassified by representing with the values as **1 = cultivated land**, 2 = **grassland**, 3 = **wetland**, 4 = **forest** and 5 = **urban area** on ArcGIS Map. Cross tabulation is a means to determine quantities of conversions from a particular land cover to another land cover category at a later date (Alphan, 2008). The change matrices based on post classification comparison were obtained and are shown in Tables 4.5, 4.6 and 4.7.

4.3.1 Cultivated Land

Agriculture has been the greatest force of land transformation on this planet. Nearly a third of the Earth's land surface is currently being used for growing crops or grazing cattle. Much of this agricultural land has been created at the expense of natural forests, grasslands, and wetlands that provide valuable habitats for species and valuable services for humankind(Millennium Ecosystem Assessment, 2003).

Cultivated land constituted 58.33%, 62.67% and 56.49% in the years 1973, 1987 and 2015, respectively (Table 4.1). The predominance of cultivated land in the area agrees with the findings of Belay (2002), in Derekolli Catchment, South Welo, Solomon (2005), in Headstream of Abay watershed and Gete and Hurni (2003) in Anjeni area of north western Ethiopian highlands. The findings of Woldeamlak (2002), in the same Region, for Chemoga Watershed Blue Nile Basin, Ethiopia, between 1957 and 1998 was a similar expansion and shrinking pattern of cultivated lands by 13% increase in 1957-1982, while 2% decrease in 1982-1998.

In the first period, cultivated land increased by 2,847.68ha (7.4%), while it decreased by 4,129.2ha (10%) in the second period (Table 4.1). In 42 years period, a transformation of cultivated land by 1,238.76ha (3.2%) was observed to grassland, forest&urban area which shared13.95, 9.05 and 1.31% respectively.

In the first period, over 24% of each LULC types were changed into cultivated land. In the same period, about 38% of cultivated land remained unchanged and 20.4% was converted into grassland and forest.

Table 4.5 Post-classification Matrixof Study Area between 1973 and 1987

		1987									
		Cultivated Land		Grassland		Wetland		Forest		Total	
		%	ha	%	ha	%	ha	%	ha	%	ha
1973	Cultivated Land	37.97	24904.44	20.06	13152.24	0.18	118.36	0.12	79.2	58.33	38254.32
	Grassland	5.75	3772.44	10.05	6591.24	0.02	11.52	0.01	6.84	15.83	10382.04
	Wetland	15.37	10076.04	1.73	1137.24	0.64	421.2	0.84	551.88	18.58	12186.36
	Forest	3.58	2349	0.51	333	0.29	187.2	2.88	1887.12	7.26	4756.32
	Total	62.67	41101.92	32.35	21213.72	1.13	738.28	3.85	2525.04	100	65,579.04

The expansion of cultivated land as shown on the satellite images in the woreda was confirmed by inhabitants that indicated that the land conversion was caused by the high numbers of the youths, who were looking for land because no employment opportunities outside agriculture were available.As indicated in chapter three the total population of the study area is increasing

from time to time and this results expansion and over utilization of the cultivated land during the first study period. But the declining of this class on the second study period implies that even if the population is keeping its growth the land couldn't give as such an expected product and the inhabitants were enforced to design another way of land use system like covering by trees.

According to FLWARDOexperts now a day the major problem for farmers in the study area is shortage of cultivable land and diminishing of land productivity. This is shown by the existence of importing cereals from neighboring DangilaWoreda. The current population pressure has created a high need for additional land.Currently triggered by the serious shortage of land, kebeles of the woreda aregiving land to landless youths from communally owned lands by organizing to small scale enterprises.Then these groups use the gained land for different purposes. For example, mostly irrigable lands use for crop production and dry lands are preferable for *Acacia decurrens* growing.

4.3.2 Grassland

In the 42 years, this category was expanded by over 43% (4475.88ha) of the original grassland cover which existed at the base year. Between 1973 and 2015, almost 80% of grassland cover was obtained from cultivated lands. This indicates that when the farmers fallow their farm land they use it as a grazing for their cattle. It is easy to convert a given land between these class categories even within year.

In 1973, this category had the smallest areal proportion next to forest. Its pattern of change showed a drastic increase by 10,831.68ha (104.33%) in the first study period. Almost 90% of cover was gained from cultivated lands. Between 1987 and 2015 the areal coverage of this category was decreased by 6,318ha (42.5%).

During the overall increasing period (1973-2015), the conversion of wetland into grassland accounted for 14.4% of the total gained grassland. In the same period, this category also gained 3.8% of its areal extent from the removal of trees. Integration among cultivated land, grassland and trees is quite strong. For example, oxen provide an important source of crop production and uses grasses to sustain; on the other hand trees serve as source of rain to cultivate crops.

This finding agrees with that of Gete and Hurni (2001) and Solomon (2005), who indicated an increase of grassland cover in Anjeni area and Headstream of Abay Watershed respectively, both in northwest Ethiopia. On the other hand, it differs from Woldeamlak's report (2002), which showed a decrease of this land cover type in Chemoga watershed, between 1957 and 1998.

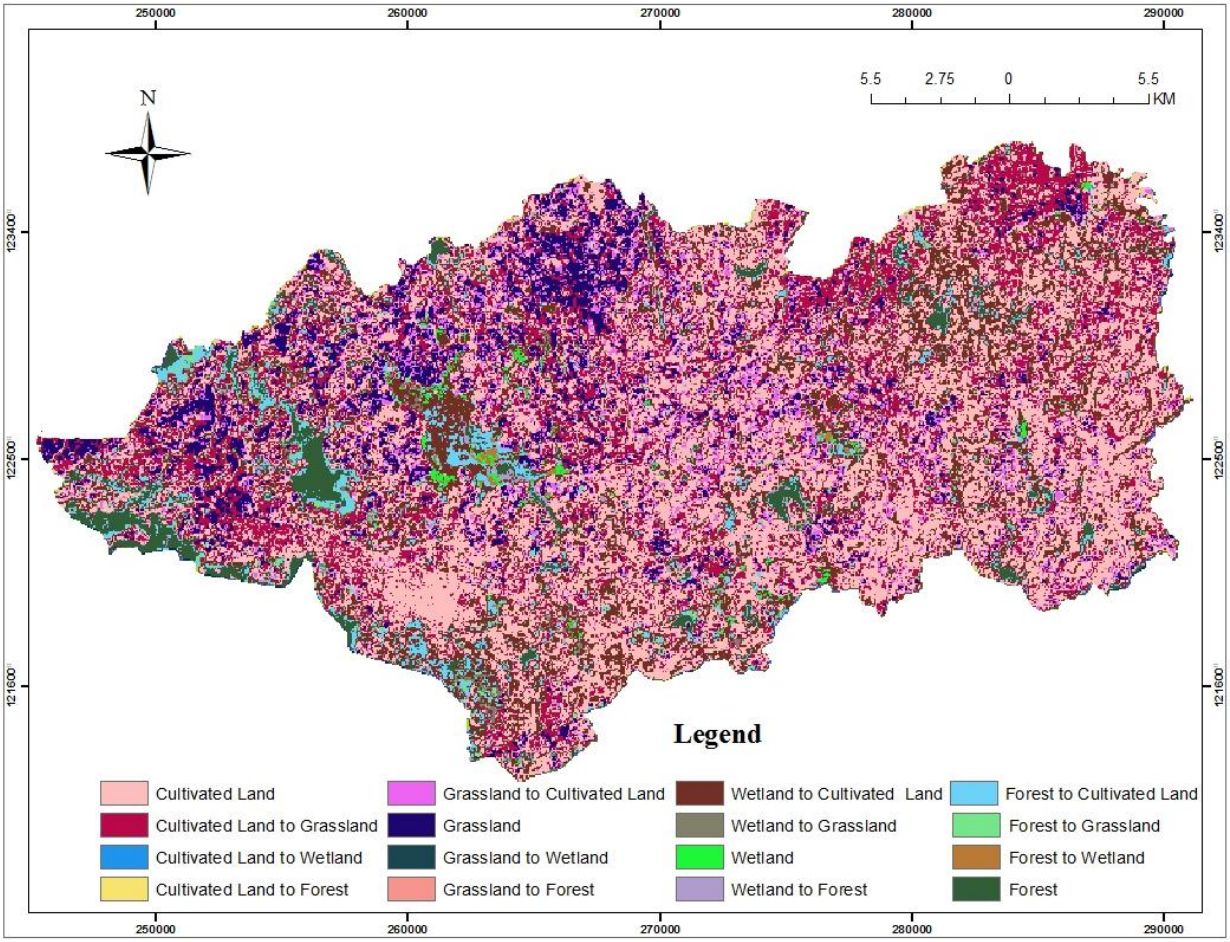


Fig. 4.5 LULC Change Map between 1973 and 1987

Discussions with elders and officers in FLWARDO revealed that the major reason for the expansion of grassland was low productivity of cultivated lands. In addition the classified satellite image revealed that as there was much change of wetlands to grassland which indicates due to dryness of the area. The physical attributes, for instance topography, accompanied with farmers low purchasing capacity of commercial fertilizers contributed to low productivity of farmlands. These two factors (topography and low productivity) make the land unsuitable to use for cultivation. As a result, they were forced to leave it for grazing land. If the fertility of this land was regained during the resting time, the land may be reused for crop production. Over 50% of what was grassland in 1973 was re-used for crop production in 2015. In addition the afforestation programs in the study area contributed its share for the reduction of grassland

during the second study period, which is as much as 1841ha. The farmers are giving more attention for covering of their land by trees because of its economic advantage when compared to the merit obtained from animal rearing.

4.3.3 Wetland

The area under wetland, i.e. the second largest landcover type next to cultivated land, was about 12,186.36ha (18.58%) in 1973 but it was diminished to 738.28ha (1.13%) in 1987 and to 128.43ha (0.2%) in 2015 (Table 4.1). Among the five LULC types, this is the most converted cover type during the entire study period. Of the total wetland cover in the base year, only 128.43ha (0.2%) remained in this category, while 61.83%, 23.4 % and 13.22% was converted into cultivated land, forest and grassland, respectively, in all periods considered.

While wetlands may be the most productive of ecosystems on earth, they are also the most threatened. Wetland destruction and alteration has been and is still seen as an advanced mode of development, even at the government level (Abebe and Gaheb, 2003).

Between 1973 and 1987, more than three fourth of wetland (10,076.04ha) was transformed into cultivated land. By the same period, 1,137.24ha (9.33%) of wetland was changed into grassland. In the second period also, greater part of wetland (78.11%) was changed into cultivated land. About a tenth of the wetland was modified to grassland between 1987 and 2015.

Consequently, during the entire period, the area under wetland shrank by around 12,019.32ha (98.63 %) with an average conversion rate of 286.17 ha/yr. The area changed from other categories into wetland was too small compared to land conversion from wetland to the other cover types.

The conversion of most wetlands to cultivated land is because wetlands have the capacity to grow crops without irrigation in winter season locally known as *Borshesh*. The major crops which are cultivated on wetland areas of the study site are potato, wheat and maize. This LULC type is found around the plain areas of the landscape, which is more preferable for farming. The other reality is that most of the wetlands are easily accessed by irrigation due to their existence at gentle slopes where rivers flow towards.

The conversion of wetlands to grassland is due to grass growth even in the dry seasons when other cover types became bare and at this time they are the only places for grazing. This through time exposes a water logged area to dryness. In the study area this is clearly shown on

*Zimbiri*area which is the widest wetland located on the western part of the study area. On this area observing a large number of animals is common. Even the neighboring kebeles were enforced to take their cattle's to this area especially in April and May. Figure 4.3 show that this area is the only part that represents the class currently and its areal extent reduced when compared to the previous image results.

4.3.4 Forests

The pattern of change for forest cover showed a decrease between 1973 and 1987 (first period), and increased between 1987 and 2015 (second period) and 1973 and 2015(the overall study period). In 1973 the area under forest cover was 4,756.32ha (7.26% of the study area) which declined to 2,525.04ha (3.85%) in 1987 (Table 4.5). Of the total forest area in 1973, 4,756.32ha, 2,231.28ha (53.1%) was cleared with in fourteen years difference. The annual clearance of forest coverwas 159.4ha.

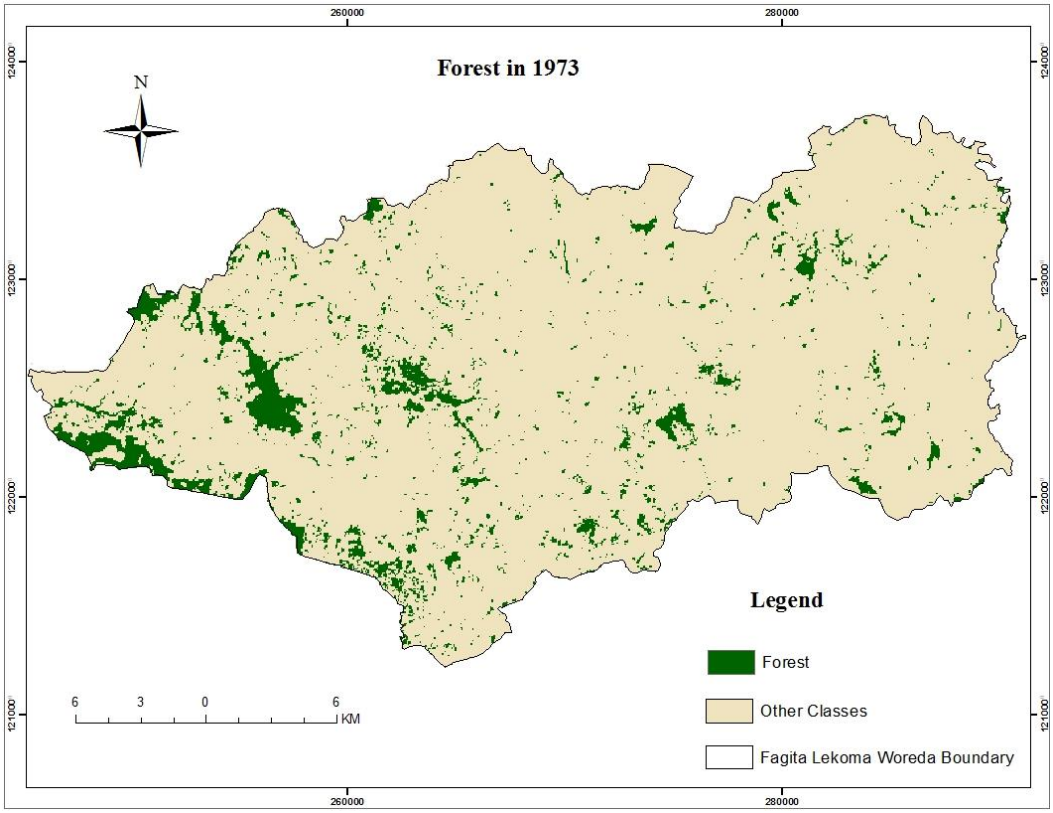


Fig. 4.6 Forest Coverage of the Study Area in 1973

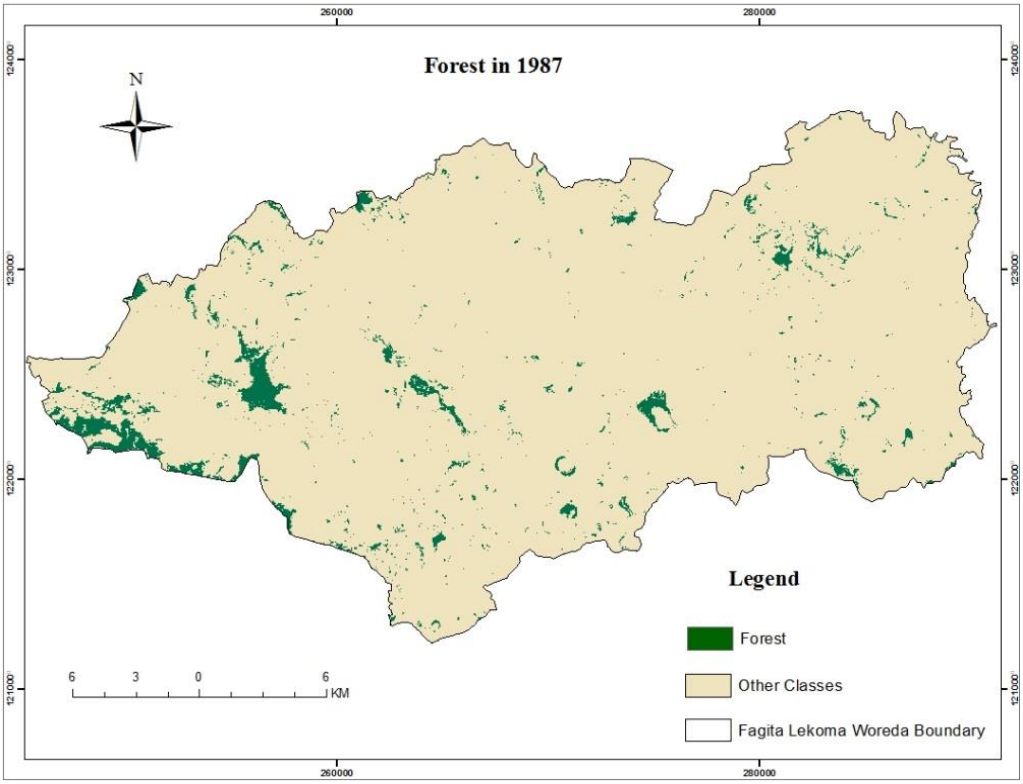


Fig. 4.7 Forest Coverage of the Study Area in 1987

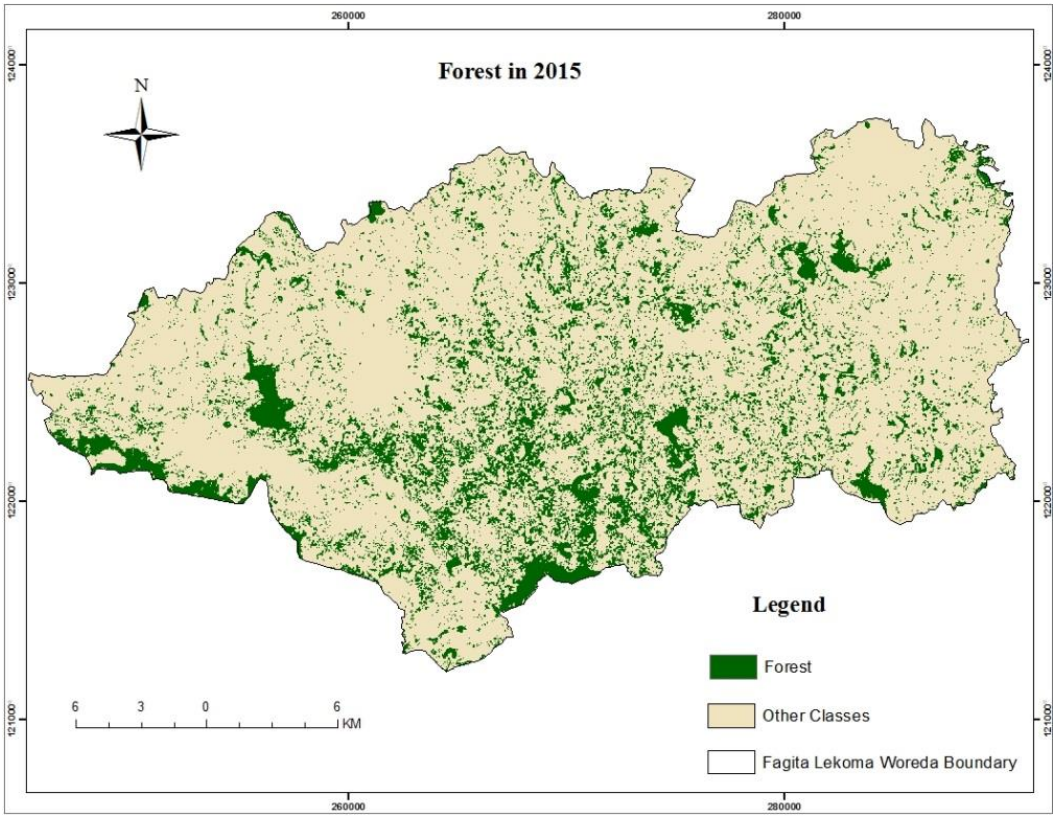


Fig. 4.8 Forest Coverage of the Study Area in 2015

Of the total forest cover in 1973, 52.1% was converted into cultivated land and 7% into grassland in 1987. Only 36.9% of the original area remained in the same category. The transformation of forest land throughout the study period was due to an increasing demand for cultivated land and grassland. That is why a large proportion of the transformed land, i.e. around 60% of the forest cover was changed into these categories. The expansion of newly established villages aroundthe irrigable lands is considered as a reason for loss of riverine trees. Farmers prefer to shift their residence from hilltops and ridges (low in productivity) to low-lying lands and areas which have better access to river water.According to the local elders the little existing remnants of natural forests (Fig. 4.2) were protected by local community. Up until now, these forests have carried the name of local leaders in the past. Even if it is difficult to avoid deforestation of natural forests totally in the area, recently the concerned government bodies in collaboration with the local community are trying to protect.

Soils in the study area have been subject to erosion over many centuries of human occupation and are now shallow and stony, with frequent rock outcrops. Soils are coarse textured, stony with low water holding capacities.The more dissected and eroded landscapes are found mainly in *AmeshaShinkuri*, *AgitaAjasta*, *ChigualiKachilta*and *Gezeherakebeles* in which most of them found southwest from Addis Kidam town. But this area is now becoming effective following the acceptance and expansion of *Acacia decurrens* tree in the area.

Table 4.6 Post-classification Matrixof Study Area between 1987 and 2015

Year		2015											
	Class	Cultivated Land		Grassland		Wetland		Forest		Urban Area		Total	
		%	ha	%	ha	%	ha	%	ha	%	ha	%	ha
1987	Cultivated Land	39.04	25602.12	10.33	6774.03	0.11	75.06	12.54	8222.67	0.76	500.22	62.78	41174.1
	Grassland	15.9	10427.49	12.19	7996.14	0.02	10.35	2.8	1841.04	1.4	907.56	32.31	21182.58
	Wetland	0.83	541.71	0.09	60.39	0.03	19.71	0.12	70.47	0	1.26	1.07	693.54
	Forest	0.72	473.58	0.052	34.02	0.04	23.31	3.03	1989.81	0.01	8.1	3.85	2528.82
	Total	56.49	37044.9	22.66	14864.58	0.2	128.43	18.49	12123.99	2.17	1417.14	100	65579.04

An attempt to recover the lost forest cover through afforestation program was practiced in the area during the second study period. As a result the coverage of forest increased between 1987 and 2015(the second study period) and on the whole entire period 1973 and 2015(four decades under study).



Fig. 4.9 Photo of *Acacia decurrens* Forest in the Study Area *(Photo by Bireda, AmeshaShinkuriKebele, August, 2014)*

The major change on forest between 1987 and 2015 has been basically characterized by introduction of *Acacia decurrens* and increasing of Eucalyptus trees. This can partly be attributed to the change in state policy in 1997 to rights of disposal of individually owned trees and to the increase in seedling availability. Two agricultural centers were established and started provision of different seedling without any cost and with little charge on some of them. Of the many seedlings provided at a time *Acacia decurrens* have gotten a wide acceptance. This is because of its match with the degraded soil, high growth rate, wanted for charcoal production and the ability revive the fertility of soil. After cutting the *Acacia decurrens* trees farmers plow this land and they are obtaining good crop products.



Fig. 4.10 Photos of *Acacia decurrens* ready for Charcoal Production (left) and in Process of Production (right)*(Photo by Bireda,AmeshaShinkuriKebele, August, 2014)*

4.3.5 Urban Area

Addis Kidam town, almost at the center of the woreda, is part of the study area. Even if there is information from the elders about the existence of the town in 1973, it hasn't any sign of town on the Landsat image. On 1987 Landsat image there are few pixels that indicate the town but their significance on the supervised classification was negligible and can't come up as a separate class from the output. This is because the houses at a time were corrugated steels and huts that make the reflectance similar with other LULC classes. Surprisingly, the size of this town has changed during the second study period and on the 2015 Landsat image, it was not difficult to identify Addis Kidam town. Small towns like Fagita and Chiguali which are located to the east and west of AddesKidam respectively arealso visible from the 2015 satellite imagery but there was no sign of settlement in both of the previous images. Currently, these small towns serve as a central place for farmers next to Addis Kidam town (Fig 4.3). Own observation and the satellite imagery showed that currently there are also other small villages which contain primary schools, health centers, tenakellas and offices of different government sector.

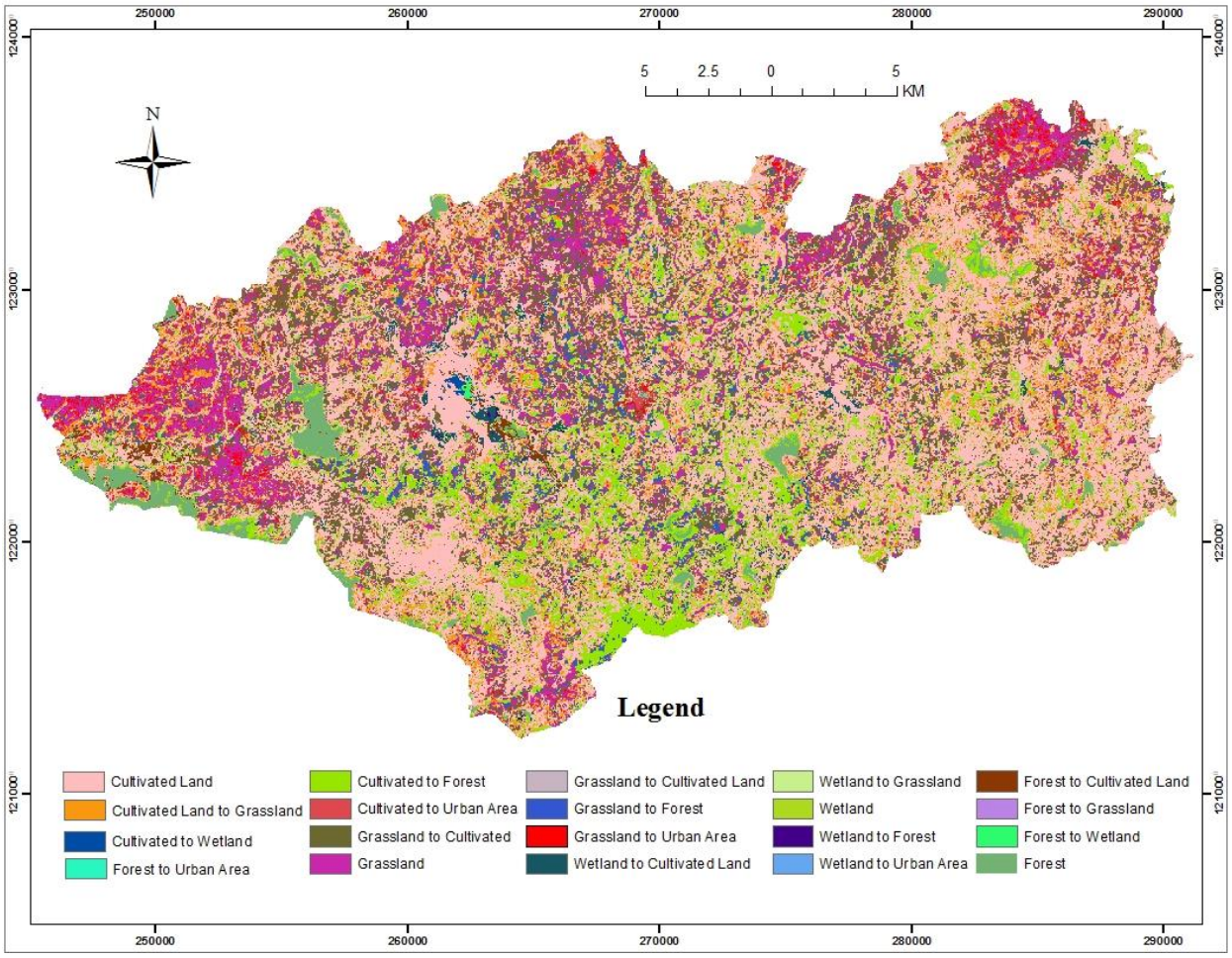


Fig. 4.11 LULC Change Map between 1987 and 2015

Area covered by urban was 1417.14ha, i.e. 2.17% of the study area in 2015. The land use and land cover change between 1973 and 1987 showed that about 64% of the net gain of urban area was due to the conversion of grassland. The remaining 35% and 0.57% were abstained from cultivated land and forest respectively.

Around Addis Kidam town basically there was a community grazing land. When the town expands this area was distributed to the community and converted to built-up areas. In rural parts of the woreda when there is a need to build schools and offices, grazing lands in general and community grazing lands in particular are preferable. This is because community grazing lands are in the hands of government and didn't require further process like privately owned lands.

Privately owned cultivated lands also were distributed to the increasing urban population by the town's municipality.

Table 4.7 Post-classification Matrixof study area between 1973 and 2015

		2015											
		Cultivated Land		Grassland		Wetland		Forest		Urban Area		Total	
	Classes												
		%	ha	%	ha	%	ha	%	ha	%	ha	%	ha
1973	Cultivated Land	34	22296.96	13.95	9149.04	0.03	1.56	9.05	5934.6	1.31	857.16	58.33	38254.32
	Grassland	7.96	5221.08	5.6	3671.28	0.01	3.6	1.59	1041.84	0.68	444.24	15.83	10382.04
	Wetland	11.49	7534.44	2.45	1611.36	0.18	115.2	4.35	2851.92	0.11	73.44	18.58	12186.36
	Forest	2.99	1963.08	0.65	426.24	0.05	21.68	3.52	2306.52	0.04	28.8	7.26	4756.32
	Total	56.41	37015.56	22.61	14844.42	0.27	128.43	18.51	1213 4.88	2.17	1417.14	100	65579.04

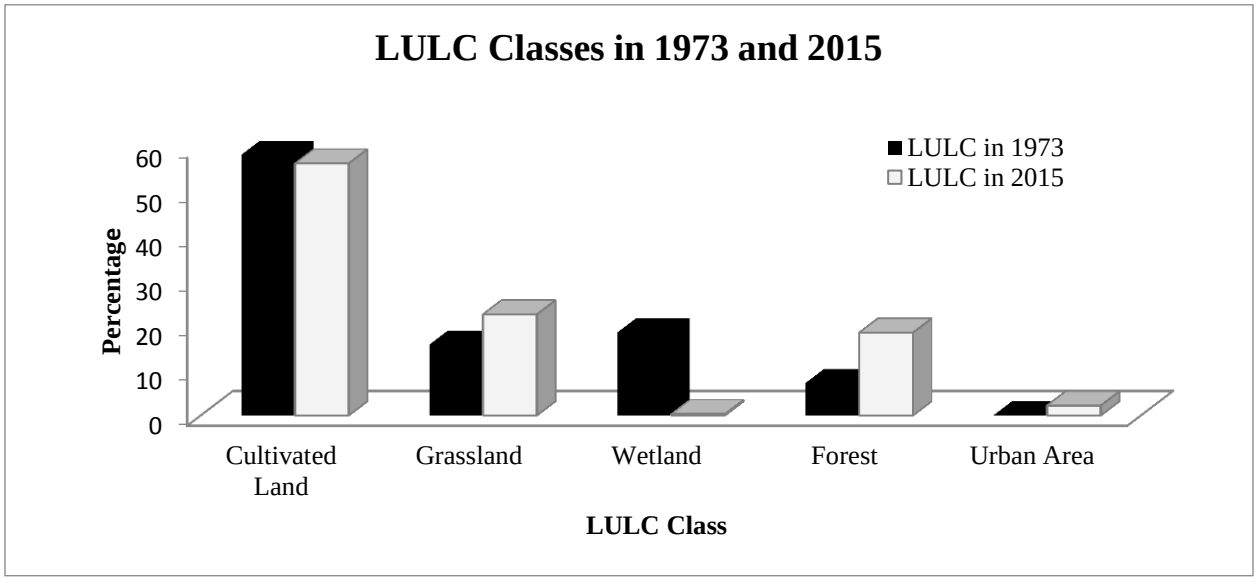


Fig.12 LULC Change Comparison between 1973 and 2015

Table 4.8 Summary of Magnitude and Rates of Change in LULC of the Study Area between 1973-1987 and 1987-2015

LULC Classes	1973-1987		1987-2015		Annual Rate of Change	
	Area Δ (ha)	%Δ	Area Δ (ha)	%Δ	1973-1987	1987-2015
Cultivated Land	2,847.6	4.5	-4,129.2	-6.3	0.32	-0.23
Grassland	10,831.68	16.5	-6,318	-9.6	1.18	-0.34
Wetland	-11,448.08	-17.6	-565.11	-0.8	-1.26	-0.03
Forest	-2,231.28	-3.4	9,595.17	14.6	-0.24	0.52
Urban Area	_	_	1417.14	2.1	_	0.08

From table 4.7, there is a negative change i.e. a reduction in wetland and forest between 1973 and 1987. This is because of the productive nature of wetlands and the clearance of trees for different purposes by community. Subsequently, both grassland andcultivated land increased by 16.5% and 4.5% respectively.

Following the afforestation measures taken and the expansion of urban areas, the forest and urban area categories were increased at the expense of cultivated land, grassland and wetland between 1987 and 2015.

4.4 Transition Probability Matrix

Marcov chain notion is cumbersome and its computations are tedious. To alleviate this problem, the more readable matrix notion is used where possible(Taha, 2007). The transition probability matrix records the probability that each land cover category will change to the other category. This matrix is produced by the multiplication of each column in the transition probability matrix by the number of cells of corresponding LULC in the later image.

For the 5 by 5 matrix table presented below, the rows represent the older land cover categories and the column represents the newer categories. The transition probability matrix used in predicting land use land cover of 2043.

Table 4.9 Transitional Probability Matrix Table Derived from the LULC Map of 1987 and 2015

Year		2015				
	Classes	Cultivated Land	Grassland	Wetland	Forest	Urban Area
1987	Cultivated Land	0.6218	0.1645	0.0018	0.1997	0.0122
	Grassland	0.4923	0.3775	0.0005	0.0869	0.0428
	Wetland	0.7811	0.0871	0.0284	0.1016	0.0018
	Forest	0.1873	0.0134	0.0092	0.7869	0.0032
	Urban Area	0	0	0	0	1

As seen from the table, cultivated land has a 0.6218 probability of remaining cultivated land and 0.1997 of changing to forest in 2043. This therefore shows a reduction, with a probability of change which is lower than stability. Grassland during this period will have 0.3775 probabilities to remain grassland and 0.4923 probability of changing to cultivated land. This implies that in addition to its reduction the majority of grassland will changed to other classes. Forest during this period will likely maintain its expansion with a 0.7869 probability of remaining forest and only 0.2131 probabilities to be changed to other categories in 2043. Wetland which is the last class has a 0.0284 probability of remaining as wetland and a 0.7811 probability of changing to cultivated land. Therefore, this shows areduction, with a probability of change which is much higher than stability.Urban area which is the new comer class in 2015 maximum likelihood classification has full probability to stable as urban area because it hasn't any history from the study year 1987. Such kind of state on Marcov Chain is called absorbing state which means that it returns itself with certainty in one transition.

4.5 Land Use/Land Cover Change Projection

The table below shows the statistic of LULC projection for 2043. The year 2043 is selected for projection because the model uses time series data and the difference between the initial year(1987) and base year(2015) was 28. When this value is added from the base year it gives 2043.As indicated from table 4.9, cultivated land still maintains the highest position in the class whilst wetland retains its least position. Forest land takes up the second position, followed by

grassland and finally, urban area. Generally the model is based on the observed pattern between the initial and a base year determines the prediction result.

Table 4.10 Projected LULC for 2043

Classes		Cultivated Land	Grassland	Wetland	Forest	Urban Area	Total
2043	Area in ha	33,211.09	10,965.97	80.82	18,102.64	3,218.52	65,579.04
	Area in %	50.64	16.72	0.12	27.6	4.92	100

The predicated result is obtained from the above discussed transition probability matrix which had the characteristics like: the sum of the rows of the probability matrix is one; the probability of the transition is same forthe base and predicted years; the state of 2043 LULC depends only on the state of 2015 and the time periodis uniform in duration between 1987-2015 and 2015-2043. Therefore, researcher believes as the prediction result is valid because the input data fulfills the requirements of Marcov Chain model listed from the previous chapter.

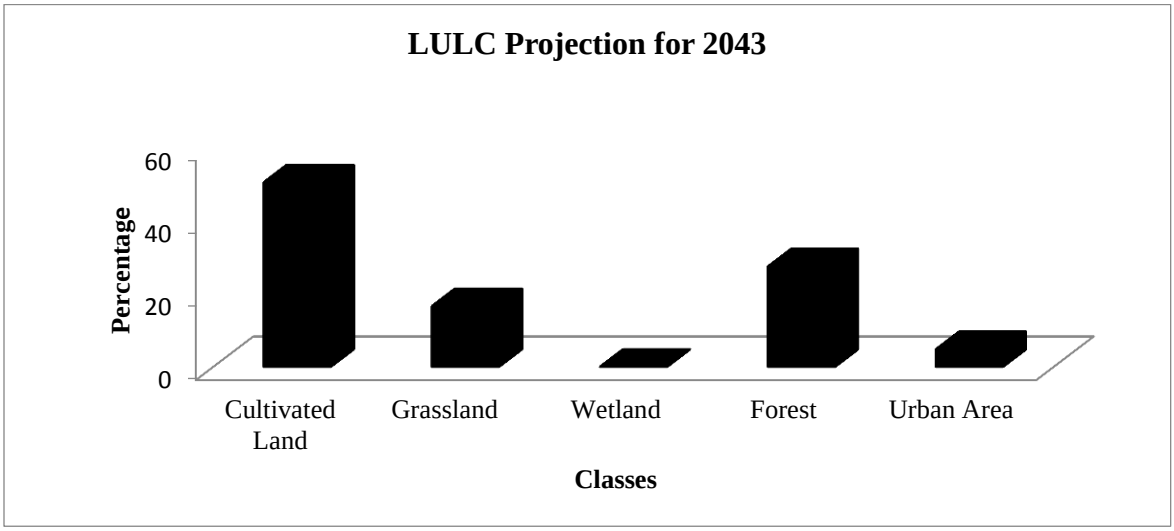


Fig. 4.13 LULC Projection for 2043

4.6 Socioeconomic Consequences of LULC Change

The socioeconomic activities of an area play an important role on the LULC type of the area. On the other hand the changes in LULC directly or indirectly affect the socioeconomic condition of a given society. The economy of the study area is based on the primary production such as crop farming, animal husbandry and charcoal production, which indicate the agrarian background. It is included under the mixed crop-livestock farming system of production.

From the changes discussed above the one which had more effect on the socioeconomic condition of the inhabitants is the change in relation to forest cover. According to the firsthand information obtained from FLWARDO, almost 90% of the woreda's population is now directly or indirectly relate with the production of *Acacia decurrens* and its effects. On both rural and urban parts of the study area the communities are producing *Acacia decurrens* seedling in their compound. These created a job to them without age and sex specification. Some of activities in relation to this are production of seedling, keeping the grown forest from cattle, cutting of it while it reached for purpose and production of charcoal.



Fig. 4.14 Charcoal Produced from *Acacia decurrens* in the Study Area(*Photo by Bireda,GullaAzmachKebele, February, 2015*)

Previously especially around the towns many youths were jobless and exposed to participate in illegal activities. But now these groups of population are working by forming three groups. The

first group serves as a broker to meet the buyers and sellers of charcoal. The second group loads the charcoal to car. Finally the third team covers the loaded charcoal and makes ready for transportation.

In the rural parts of the study area previously most of the young populations were employed as a servant with in and out of the woreda, migrate to Addis Ababa and different parts of the country. Now a day thanks to this golden kind of forest these is becoming a history, they are engaged on starting from the production of seedling to the production and provision of charcoal which enables to lead a better life in their birth place.

Such kind of activities requires large labor force because they are wide and continues throughout the year. Females also participate basically on preparation of the inputs to produce seedling, watering the seedling and the transportation of the charcoal product from inaccessible areas.

In general *Acacia decurrens* is serving as a cash crop in the woreda. For example, as indicated from the report of FagitaLekomaWoreda Revenue Office (FLWRO) in 2013/2014 (2006 E.C. budget year) the woreda obtained more than 4 million ETB from the exported charcoal as royalty tax. Now the woreda is one of the major providers of charcoal to Addis Ababa city's population and other parts of the country. Exporting the product to Sudan through Metema is also started which implies as it will be an important source of income to the woreda in particular and to country in general.

The government employees and merchants are also the beneficiaries of this LULC change. Being a government employee at woreda level and having a car is very difficult really now. But more than three who were government employees could do this by changing their job to trading charcoal.

Before the past ten and fifteen years almost all of the rural residents of the study area were inhabited in huts and looking steel houses was endemic. Now a day in order to have such asset having a land by itself is enough. Those farmers who haven't the capacity to cultivate their land can rent to somebody and utilize it. Now the majority of the rural population leaves in steel houses and they are also constructing additional homes at urban areas.

In addition the farmers are learning technical way of using their land like generating two purposes from a given land at the same time. When they need to grow the *Acacia decurrens* they

plow the land and grow with the crop together. On the next two and three years they use the grass inside for their cattle's as a food source. So, the land which is covered by this type of forest becomes out of such additional advantages not more than three and four years. When the forest becomes from five to seven years old, it will be removed to produce charcoal and replaced by another.

Despite the above mentioned advantages, due to the LULC change in general and the expansion of forest in particular the farmers are facing problems like shortage of farmland and grazing lands. As already mentioned in the previous chapter,these are more shown by the existence of importing cereals for consumption. There are also farmers who exposed to different social and economic problems by renting almost all of the land they have.

CHAPTER FIVE

5. CONCLUSION and RECOMMENDATIONS

5.1 Conclusion

LULC changes have wide range of consequences at spatial and temporal scales. Because of these effects and influences it has become one of the major problems for environmental change as well as natural resource management. Identifying the complex interaction between changes and its drivers over space and time is important to predict future developments, set decision making mechanisms and construct alternative scenarios.

This study has been conducted by integrating GIS and Remote Sensing. In order to detect and analyze changes in land cover classes, these techniques were implemented. In the first section, satellite data for the study periods of 1973, 1987 and 2015 and Remote Sensing techniques were applied to generate LULC maps through a maximum likelihood supervised image classification algorithm. The accuracy assessment and change detection processes has also been done. The overall accuracy of land use and land cover maps generated in this study had got an acceptable value of above the minimum threshold. In the last section, LULC projection was applied using Marcov Chain model to show changes in the future.

From the remote sensing of image classification result, the woreda showed significant change in the LULC over the last four decades. The changes were largely caused by increased population growth and land degradation. From the observed changes expansion of forest coverage and growth of urban areas can be taken as something positive.

In the first study period the study area was covered by four LULC categories namely cultivated land, grassland, wetland and forest. During the second study period the number of LULC types has increased to five categories. Presently it adds a new LULC class which is urban area at the cost of cultivated land and grassland.

From the observed changes wetlands are the most converted (98.63%) cover type during the entire study period and surprisingly forests increased by 254% (7,378ha). The expansion of this LULC type is due to decrement on the productivity of cultivated land which opened the way for the introduction and expansion of *Acacia decurrens*. The socioeconomic condition of the study area community had largely affected by the changes on this LULC type.

5.2 Recommendations

The results of this study have shown that Remote Sensing and GIS are important tools in LULC change studies. Therefore, based on the findings of this study, the following recommendations are forwarded for policy implications and future research directions:

- The use of high resolution imageries such as IKONOS and Quick Bird are important in generating good quality of LULC maps. Because it is difficult to map small parcels of LULC like urban areas in 1973 and 1987 study periods and high resolution imagery provide better information by mapping these areas. Therefore, for future studies it is better to use high resolution images to fill such kind of gaps. Moreover, the use of ancillary data as ground truth helps for better accuracy of an image classification.
- There should be an appropriate land use planning and policy with impact studies and scenarios, in order to use a given land with its maximum output. In addition the farmers should be aware of their land use system. Because they are covering their land with *Acacia decurrens* only by considering the money that will be obtained from charcoal product after five to seven years. This activity is shown sometimes even on irrigable lands which can give merit twice a year. Therefore, when farmers need to cover their land by *Acacia decurren*s the concerned government body should approve as the land is not productive for crop cultivation. Such policy alsowill be enabling to identify the proper land for specific purpose so that the marginal lands like wetlandwill not be put intouse.
- Population increase has played a major role on LULC change and there should be strong family planning awareness creation campaigns with adequate health services from the zonal and woreda health extension services (offices). To minimize the problems of landless youths, it will be imperative to create and strengthen off-farm income generating activities due to limited capacity of land to accommodate additional population.
- To make the woreda's community more profitable the charcoal production system should be supported by results of modern technology.Because the communities now days are practicing traditional way of charcoal production system and during this process there are woods that will be changed to ash and the producers are also exposed to health problems.
- I recommend integration of socio-economic data, land policy scenarios, biophysical parameters and demographic variables when predicting future LULC patterns.

Incorporation of the above variables would improve model performance and provide accurate prediction of the future LULC patterns in the study area.

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Appendix

***Appendix I*: Monthly Maximum Temperature (in ^{o}c) of the Study Area from 1987 to 2014**

Eg el abbreviation	Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
TMPMAX	1987						25.7	25.8	25.1	25.9	25.6	26.4	28
TMPMAX	1988	29.9	29.1		29.9	26.3	22.8	20.8	20.7	21.8	22.4	23.4	24.4
TMPMAX	1989	24.8	25.5	25.7	26	24.4	22.7	21.8	22	22.9	23.3	24.6	24.1
TMPMAX	1990	25.6	25.4	27.1	27.9	26.8	23.8	21.7	22.2	22.5	24	25.1	26
TMPMAX	1991	26.3										24.1	24.2
TMPMAX	1992	24.6	25.5	27.9	26.8		24.4	21.4	20.5	23.3	23.9	22.6	23.7
TMPMAX	1993	24.1	25.1	27	25.5	25.3	22.2	20.9	21.9	22	22.6	23.8	25.1
TMPMAX	1994	26.4	26.7	27.7	28.5	25.5	22.1	20.2	20.7	22.6	24.3	24.7	25.6
TMPMAX	1995	26.6	27.1	27.2	27.9	26.5	24.5	21.3	21.7	23.2	24.5	25.2	25.5
TMPMAX	1996	25.8	28.1	27.3	27.1	24.2	22.6	21.9	22.1	22.9	23.9	23.8	24.6
TMPMAX	1997	25.5	27.2	27.6	26.7	24.1	23.3	21.7	22.4	24.2	23.3	24.3	25.4
TMPMAX	1998			28.3	29.8	26	23.9	20.7	21.1	23.1	23.7	24.6	25.3
TMPMAX	1999	25.7	28.6	27.6	28.1	25	23.7	20.6	21.5	22.7	22.4	24.2	24.8
TMPMAX	2000	26.3	27.6	28.7	25.6	25.5	22.8	21.7	21.4	23.2	22.9	24	24.9
TMPMAX	2001	25.3	27.7	27.2	28.5	25.8	22.4	21.5	21.4	23.2	23.7	24.3	25.6
TMPMAX	2002	26	28	27.9	29.2	28.1	23.4	23.4	22.1				
TMPMAX	2003	26.8	28.3	29.1	29.5	29.6	24.2	21.8	22.4	23.5	24.6	25.6	26.1
TMPMAX	2004	27	27.6	29.1	27.5	27.9	23.3	22.6	22.6	23.3	23.9	25.2	26.1
TMPMAX	2005	26.3	29.7	29.1	29.6	28	24.4	21.1	22.2	23.1	23.6	25.2	26.2
TMPMAX	2006	27	28.5	28.7	28.3	25.1	23.8	22.3	22.1	23	23.7	25	25.3
TMPMAX	2007	25.8	27.6	28.8	28.2	26.3	22.9	21	21.9	23	24.3	25.2	26.3
TMPMAX	2008	26.2	27.2	29.3	26.5	25	23.7	22.3	22.7	23.7	24.4	26.1	26.6
TMPMAX	2009	27.1	28.4	29.2	28.7	29	25.3	22.1	22.7	24.5	24.4	25.9	
TMPMAX	2010		28.8	28.9	29.6	26.4	24.9	21.9	23.3	23.3	24.7	25.7	25.5
TMPMAX	2011	25.9	28.6	27.6	29	26.1	24.1	22.7	22.4	23.3	24.8	25.5	26.2
TMPMAX	2012	27.2	29.3	29.8	29.2	28.3	24	22.4	22.5	23.4	25	24.3	25.8
TMPMAX	2013	27.2	29	29	29.3	26.6		22.4	21.2			24.9	25.4
TMPMAX	2014	26.6	27.5	27.7	27	25.1	24.2	22.6	25.5	25.5	25.5	25.5	25.5

Source: National Meteorological Agency(Dangila Station)

Appendix II: **Monthly Minimum Temperature (in ^{o}c) of the Study Area from 1987 to 2014**

Eg el abbreviation	Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
TMPMIN	1987						13.9	12.1	11.9	10.2	10.3		6.4
TMPMIN	1988	4.2	5.1		9.2	13.2	12.7	12.6	12.1	12.1	10.7	7.1	4.6
TMPMIN	1989	4.3	5.5	8.7	9	11.9	11.8	11.7	12	11.5	10.4	7	6.4
TMPMIN	1990	6.8	6.8	7.9	10	12.5	12.5	12.1	12.4	11.6	10.4	6.8	5.5
TMPMIN	1991	7.1										4.3	2.1
TMPMIN	1992	2.6	3.3	7.6	9.5		9.9	9.7	10.1	8.9	9.1	6.3	4
TMPMIN	1993	2.9	3.9	6.9	9.8	9.2	10.2	10.3	10.1	9.5	9.1	6.6	4.1
TMPMIN	1994	4.2	5.7	5.8	11	11.5	11.5	11	10.6	10	7.9	6.9	4
TMPMIN	1995	3.5	5.6	6.5	9.8	11.8	11.3	11.6	11	9.7	8.5	5.6	5.4
TMPMIN	1996	3.8	5.6	8.4	9.8	10.6	10.5	10.5	10.8	9.7	7.7	5.9	4.3
TMPMIN	1997	3.5	4.3	8.9	9.3	10.8	9.9	10.7	10.3	9.7	9.2	7.2	4.8
TMPMIN	1998			11	12	13.2	12.4	13	12.8	11.9	10.9	6.6	3.7
TMPMIN	1999	4.4	6.9	5.1	11	11.1	10.3	10.9	10.7	9.5	9.6	5	3.9
TMPMIN	2000	3.5	4	5.3	8.2	9.6	8.9	9.2	9	8.6	8.5	5.3	5.3
TMPMIN	2001	3.4	7.1	8.4	12	11.9	12.6	12.8	12.9	11.3	11.4	7.4	6.3
TMPMIN	2002	5.9	7.7	9.8	9.7	12.1	13.1	12.7	12.2	11.1	10.1	7.4	4.6
TMPMIN	2003	4.1	7.9	10	9.5	12.4	12.8	13.3	13	11.7	10	8.2	5
TMPMIN	2004	5.3	6.6	8.7	12	11.2	12.7	12.2	12.3	11.3	9.3	8.4	5.7
TMPMIN	2005	4.5	7.4	9.4	12	10.7	12.6	12.7	12.3	12	11	7	3.8
TMPMIN	2006	5.8	8	8.4	11	12.7	12.5	12.8	12.8	12.1	9.2	8.1	6.4
TMPMIN	2007	5.5	6.7	9.5	12	13.2	13.3	12.7	12.5	12.1	10.4	7.6	3.9
TMPMIN	2008	6.8	6.4	8.7	13	12.5	12.2	11.9	12.2	11.6	10.3	6.6	5.5
TMPMIN	2009	5.5	9.4	10	10	11.5	12.6	12.7	12.8	11.5	10.5	7.1	6
TMPMIN	2010	5.9	7.7	8.4	12	13.5	12.9	12.6	12.2	12.2	11.4	8.1	5.9
TMPMIN	2011	5.5	6.1	9.2	11	12.3	12.8	12.8	12.3	12.2	10.6	7.6	5.5
TMPMIN	2012	5.5	5.7	8.7	8.7	11.7	12.6	12.7			9.7	9.2	6.7
TMPMIN	2013	6.6	6.9	8	9	13.1		12.7	12.3			8.7	5
TMPMIN	2014	6.1	6	11	13	12.9	13	13.1	12.3	11.9	11.7	8.6	6.1

Source: National Meteorological Agency(Dangila Station)

***Appendix III*: Monthly Rain Fall (in MM) of the Study Area from 1987 to 2014**

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1987	3	14					286.1	384	216.4	123.8	0	0
1988	4.2	15.6		0	91.2	354.4		384.9	267.6	270.1	29.5	0
1989	0	0	60.3	73.5	157.4	226.8	448.6	369.9	237.9	58.9	4.4	8.5
1990	5.9	0		2.8	62.1	246	469.9	479.2	268.1		3.9	0
1991	0										19	0
1992	0	0	4.1	65.8		140.6	292.8	345.7	200.6	155.2	85.3	34.9
1993	0	2	45.9	60.8	166.2	238.5	369.4	344.8	324.2	148.1	15.7	0
1994	1.6	6.2	0	29.5	135.9	279.8	248.4	355.5	180	32.8	35.4	12.8
1995	0.6	0	61.1	41.5	130.2	209.2	220.8	263	177.9	55.8	3.3	21.2
1996	0	1.9	97.4	94.3	182.4	185.6	339.8	385.9	249.7	74.2	43.2	0.3
1997	0	0	35.7	52.5	209.5	205.9	351.4	379.7	175	163.6	90.5	3.4
1998	0	0	22.7	13.9	186.1		282.3	343.2	254.2	148.3	5.8	0
1999	2	0	0	36.3	243.7	280.8	388.8	370.8	329.5	263.9	35.8	7.8
2000	0	7.1	7.5	77	135.3	344.1	313	436.1	237.8	265.3	70	2.5
2001	0	0	14.5	13.9	157.3	318.3	389.5	259.3	150.3	97.6	3.3	7.1
2002	0	3.6	11.9	14.8	52.1	278.8	298.9	351.7	182.7	123	30.3	2
2003	0	4.5	7.5	2.2	23.1	330.6	338.8	279	301.9	26.8	55	0
2004	0.5	9.1	2.3	90.5	60.7	230.5	488.2	363.8	266.6	94.7	21	0
2005	4	0.5	29.2	7.4	48.1	270.9	318.5	344.7	320.7	54.1	7.3	0
2006	2.9	0	0	47.9	258.9	339.7	440.2	392.9	227.6	133.1	6.8	19
2007	0	1	12.3	50.6	131.7	268.1	314.3	384.4	197.7	60.3	58.3	0
2008	40.1	0	4.8	119.7	251.1	292.1	434.6	421.9	256.4	28.6	6.8	2
2009	0	6.9	18.8	11.9	24	317	334.1	433	121.3	160.7	26.6	0.3
2010		0	0.5	31.5	149.9	192	339.9		290.1	67.3	14.2	4.8
2011	4	2	31.2	20.5	228.8	271.9	339	432.7	217.1	48	4	0
2012	0	0	2.7	0	63.8	286.9	412.6	500.6	189.7	52.7	107.6	23.8
2013		0		0	169.4		570.2	376.1			13.2	1.7
2014	0	3.9	56.5	134.7	302.5	248.6	360.4	314.4	341.2	195.7	49	1.3

Source: National Meteorological Agency(Dangila Station)

Appendix IIV: Ground Control Pointsfor Image Interpretation and Classification

LULC	X	Y	LULC	X	Y
Forest	247716	1222450	Cultivated Land	261961	1221669
Forest	248599	1222565	Cultivated Land	259757	1226832
Forest	249291	1222533	Cultivated Land	262297	1230343
Forest	249964	1222470	Cultivated Land	269631	12296657
Forest	249564	1223498	Cultivated Land	268146	1224387
Forest	249422	1223405	Cultivated Land	268971	1223346
Forest	250711	1228790	Cultivated Land	269314	1221326
Forest	252921	1228745	Cultivated Land	267714	1218139
Forest	254331	1227482	Cultivated Land	273378	1220132
Forest	255677	1226193	Cultivated Land	275245	1226368
Forest	256249	1225316	Cultivated Land	279830	1223142
Forest	256337	1224650	Cultivated Land	278636	1219917
Forest	263199	1225456	Cultivated Land	280249	1223104
Forest	261860	1225049	Cultivated Land	281011	1221491
Forest	262945	1224194	Cultivated Land	284084	1221237
Forest	265665	1222858	Cultivated Land	287532	1220539
Forest	265819	1220715	Cultivated Land	288453	1222275
Forest	263395	1219128	Cultivated Land	287606	1224095
Forest	270978	1218629	Cultivated Land	287638	1227217
Forest	274610	1223405	Cultivated Land	285923	1228910
Forest	277214	1225373	Cultivated Land	288802	1230074
Forest	272745	1222403	Cultivated Land	283479	1231852
Forest	272723	1225965	Cultivated Land	287342	1235906
Forest	273696	1232383	Cultivated Land	279245	1226635
Forest	274865	1231574	Cultivated Land	270300	1227874
Forest	279419	1233336	Cultivated Land	268294	1224229
Forest	280329	1233791	Cultivated Land	264027	1226121
Forest	290119	1232803	Cultivated Land	268484	1230350
Forest	289288	1230992	Cultivated Land	266524	1230825
Forest	290151	1232881	Cultivated Land	267633	1235422
Forest	288054	1219898	Cultivated Land	256618	1222866
Forest	289076	1220672	Cultivated Land	253841	1225042
Forest	287127	1222082	Cultivated Land	270123	1229047
Forest	284142	1220247	Cultivated Land	278420	1229450
Forest as Wetland	285114	1222965	Cultivated Land	263635	1231444
Forest as Wetland	262683	1226108	Cultivated Land as Grassland	268733	1228331
Wetland	260206	1227509	Cultivated Land as Grassland	271435	1228754
Wetland	261050	1227293	Cultivated Land as Grassland	282181	1228150
Wetland	261895	1227223	Cultivated Land as Grassland	287096	1227250
Wetland	262117	1226747	Cultivated Land as Grassland	288472	1225089
Wetland	261634	1224492	Cultivated Land as Grassland	276778	1221369

Wetland	263698	1224143	Cultivated Land as Grassland	274377	1220289
Wetland	267838	1223413	Cultivated Land as Grassland	273179	1219871
Wetland	266577	1218103	Cultivated Land as Grassland	270297	1216688
Wetland	267999	1217121	Cultivated Land as Grassland	268509	1221903
Wetland	264824	1215225	Cultivated Land as Grassland	264241	1220164
Wetland	263046	1214149	Cultivated Land as Grassland	247739	1224072
Wetland	259295	1222396	Cultivated Land as Wetland	273411	1219693
Wetland	247307	1225012	Cultivated Land as Wetland	279957	1222747
Wetland	247525	1224029	Cultivated Land as Wetland	272095	1232345
Wetland	246953	1223341	Grassland	266859	1231988
Wetland	248620	1223235	Grassland	266387	1231226
Wetland	253557	1227315	Grassland	264939	1232780
Wetland	254224	1228813	Grassland	266219	1234838
Wetland	255610	1228379	Grassland	262806	1231510
Wetland	256722	1231056	Grassland	259959	1228620
Wetland	257611	1232004	Grassland	258763	1227424
Wetland	258918	1231363	Grassland	251947	1227414
Wetland	261373	1229781	Grassland	253355	1225477
Wetland	264315	1229326	Grassland	251926	1224567
Wetland	265712	1230945	Grassland	250741	1225530
Wetland	265649	1234131	Grassland	249587	1226080
Wetland	269239	1231024	Grassland	247121	1225361
Wetland	271516	1231684	Grassland	245809	1225435
Wetland	273861	1231193	Grassland	269860	1221654
Wetland	276875	1227247	Grassland	276007	1221485
Wetland	281992	1230742	Grassland	277158	1224596
Wetland	286014	1234565	Grassland	275407	1227517
Wetland	288342	1234909	Grassland	275724	1229401
Wetland	284454	1226222	Grassland	272692	123234
Wetland	283707	1221446	Grassland	278788	1231152
Wetland	276772	1220472	Grassland	286387	1234867
Wetland	276835	1227140	Grassland	287562	1230877
Wetland	281115	1229133	Grassland	287122	1226289
Wetland	270375	1220646	Grassland	285831	1223569
Wetland as Forest	269588	1227283	Grassland	284337	1222528
Wetland as Forest	261350	1227291	Grassland	281131	1223356
Wetland as Forest	261477	1227431	Grassland	280801	1226567
Wetland as Forest	262195	1227155	Grassland	276145	1221976
Wetland as Forest	259976	1227428	Grassland	274144	1222743
Wetland as Forest	261360	1225389	Grassland	269866	1221666
Wetland as Forest	260700	1225097	Grassland	266190	1214210
Wetland as Forest	264478	1224180	Grassland	263643	1213414
Wetland as Forest	264176	1225100	Grassland	263455	1220841
Wetland as Forest	264534	1229107	Grassland	262582	1222050
Wetland as Cultivated Land	279954	1224890	Grassland	260550	1224493

Cultivated Land	251312	1224781
Cultivated Land	253629	1226660
Cultivated Land	253998	1223384
Cultivated Land	253363	1222190
Cultivated Land	255865	1222088
Cultivated Land	257757	1221136
Cultivated Land	259821	1219828
Urban Area	268828	1225500
Urban Area	269113	1225485
Urban Area	269332	1225631
Urban Area	269336	1225859
Urban Area	268904	1226012
Urban Area	285951	1223885
Urban Area	285946	1224127
Urban Area	285704	1224223
Grassland	259305	1226221
Grassland	258763	1227414
Grassland as Cultivated Land	259613	1230665
Grassland as Cultivated Land	259614	1231803
Grassland as Cultivated Land	265620	1233246
Grassland as Cultivated Land	285299	1220691
Grassland as Cultivated Land	269872	1220404
Grassland as Cultivated Land	257600	1223280
Urban Area as Grassland	269185	1225689
Urban Area as Grassland	268945	1225930
Urban Area as Grassland	269516	1226077
Urban Area as Cultivated Land	269215	1225509